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Breeding behavioral activities of captive red pandas in Nepal

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Abstract The red panda (*Ailurus fulgens*) population is decreasing, with less than 10,000 individuals in the wild because of habitat destruction, fragmentation, and illegal hunting. Captive breeding has become an increasingly crucial strategy for conserving endangered species, but efforts to generate self-sustaining populations have failed despite ample resources being allocated. Animals are often stressed in captivity, and it is necessary to examine reproductive behavior relating to the complexity of habitat requirements, dietary preferences, and, in particular, pregnant mothers and their sensitivity to disruptions. Using videography, we observed the reproductive behavior of two red pandas along with other behavioral activities in the Central Zoo, Kathmandu, Nepal. We collected behavioral data from December 2020 to June 2021 using scan and focal sampling. Reproductive behaviors (e.g., scent-marking, allogrooming, chasing, running, aggressiveness, mating, and feeding feces) were observed, along with behaviors like locomotion, climbing, standing, self-grooming, feeding, sleeping, self-play, and stretching. We observed 1–2% of reproductive behavior from total activity. Copulation was attempted on three occasions suggesting reproduction can be successful if animal husbandry is properly managed. We recommend zoo managers further refine strategies for captive breeding endangered species such as red pandas. Successful captive breeding benefits the zoo, and captive-born animals can mitigate extinction in the wild.

Keywords: behavior, breeding, captivity, endangered species, Zoo

1. Introduction

Conservation of carnivore species has become challenging as human intrusions and disturbances have altered natural systems through habitat loss and fragmentation, climate change, and invasive species (Wei et al 1999; Marneweck et al 2021). The red panda *(Ailurus fulgens)* is a carnivore species categorized as globally endangered on the IUCN Red List of Threatened Species (Glatston et al 2015). Red pandas inhabit sub-tropical and temperate alpine forests in the Himalayas and southern China (Roberts and Gittleman 1984; Yonzon 1989; Yonzon and Hunter 1991; Sharma and Belant 2009; Glatston et al 2015). There are two red panda subspecies separated geographically by the Nujiang River in Yunnan, China, with *A. f. fulgens* distributed in Bhutan, India, and Nepal, and *A. f. styani* in China and Myanmar (Wei et al 1999; Choudhury 2001; Groves 2011; Dorji et al 2012). The red panda is a bamboo specialist whose diet is > 90% bamboo with opportunistic consumption of fruits, small birds, eggs, insects, mushrooms, and other grasses (Yonzon and Hunter 1991; Wei et al 1999; Pradhan et al 2001; Dorji et al 2012).

The red panda population is declining throughout its range, with probably < 10,000 individuals in the wild (Glatston et al 2015). The breeding success of red pandas in the wild appears low, likely due to isolated populations and high cub mortality (Yonzon 1989). Consequently, many zoos in Europe and Asia have established captive breeding programs and developed strategies to release red pandas into the wild and distribute them to other zoos. The success of red panda captive breeding programs can likely support the demand for red pandas in zoos and reduce their dependency on wild populations. However, reproductive success will depend on their behavior in captivity.

Conservation managers increasingly turn to ex-situ conservation breeding projects to prevent species loss and/or restore natural populations (Ramirez et al 2006; Conde et al 2011). Unfortunately, ex-situ conservation to save threatened species is challenging (Kiik et al 2013). Capture and transport of individuals, adjustments to new and artificial surroundings, and interactions with conspecifics or other species are stressful, in addition to the high cost of captive breeding programs (Kathleen and Tomborg 2007). Captive animals have less opportunity to express typical behaviors, resulting in more rigid and repetitive behavior (Vanhoomissen 2016). The life expectancy of captive species is sometimes lower than in natural conditions (Roberts and Gittleman, 1984), which can reduce breeding opportunities. Hence, successful and cost-effective breeding programs rely largely on developing behavioral management strategies

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driven by applying scientific knowledge (Zhang et al 2004; Martin-Wintle et al 2017). The study of reproductive behavior in captivity, considering characteristics of the captive environment and the species' biology, would benefit the successful breeding of threatened species. Conservationists can further use this information to establish or improve captive management plans. Our objective was to quantify the behavior of captive red pandas, particularly reproductive behavior, to improve our understanding of *ex-situ* conservation strategies.

2. Materials and Methods

The Central Zoo of Nepal was established in 1932 and comprises six hectares, housing more than 1,000 individuals of 113 species (Central Zoo; July 15, 2022). It is Nepal's primary facility for rescuing and rehabilitating animals, and an estimated one million people visit the zoo annually.

The red panda enclosure includes 132 m^2 of open space with a small attached single-level structure with air conditioning. The open area is natural, containing a mature Camphor tree *Cinnamomum camphora* and bamboo plants. The tree contains an artificial nest box on one of its branches. Visitors can view red pandas from behind walls that encircle the open area. The 28 m^2 person-made structure is separated into two compartments for each of the two red pandas housed. The compartments are partitioned with 60 cm high walls and lattice iron bars above such that red pandas can see, smell, hear, and have limited physical contact through the bars. Wooden planks and logs were fixed inside each enclosure along with nest boxes, and the female enclosure had a staircase. This building also provides security for visitors. Each morning the floor of the entire structure is cleaned using disinfectant and then rinsed with clean water.

Our study included two red pandas (1 male and 1 female; Figure 1). Male red pandas weigh 3.7–6.2 kg, and females 4.2–6.0 kg (Roberts and Kessler 1979). Red pandas begin breeding in early December, and females have 114–145 days gestation, with births occurring primarily during June–July (Glatston 2021).

Figure 1 Red pandas housed in the Central Zoo, Kathmandu, Nepal (Female in foreground).

We collected data using videography during the reproductive season (December 15, 2020–June 3, 2021). We attached eight closed-circuit (cc) cameras inside and outside the enclosure to provide complete visibility and monitor activity throughout the diel period. Red pandas were provided periodic access to each other's enclosure for familiarization on December 15 and were housed together from December 17, 2020 to June 3, 2021. From our literature review and preliminary review of videos, we developed an ethogram of 22 non-reproductive and reproductive behaviors (Table 1).

We conducted scan and focal sampling to document behaviors (Altmann 1974). For scan sampling, we recorded the behavior of each red panda every 15 minutes throughout the diel period. For focal sampling, we recorded the duration of each behavior for each Red panda for 10 min every two hours.

We used Mann-Whitney U tests to compare differences between male and female red panda behaviours in R program R (R Core Team 2022). We used descriptive statistics to determine overall reproductive and non-reproductive behavior activity budgets. We summed the overall time spent for each behavioral category, then divided the values for each behavior by the total value obtained of the behavioral category under which was categorized and converted to percentages.

3. Results

Overall, we recorded 16,416 events from scan sampling; 96% (n = 15,701) of male activity and 95% (n = 15,643) of female activity was non-reproductive behaviors (Figure 2). The male and the female spent 1% (n = 242) and 2% (n = 300) of their time for reproductive behavior, respectively.

Type	Behavior	Description
Non-reproductive behavior	Locomotion	Using all four limbs running or bounding on ground, logs, and tree branches
	Climbing	Climbing up or down a tree trunk, branch, stairs, wall, or elevated surface (horizontal or vertical)
	Standing	Standing on all fours or on back feet motionless
	Sleeping	Lying-sleeping (curled in a ball or lying flat); unresponsive to noise/activity
	Resting	Lying or sitting, head up, eyes open, reaction to surroundings in some manner (head, eye, ear or tail movement)
	Self-grooming	Scratching or licking fur or skin in a consistent repetitive action on self
	Feeding	Eating provisioned food or browsing in enclosure or open natural space
	Drinking	Drinking provided water
	Defecation/ Urination	Discharge of feces/urine from body
	Response to human	Paying attention to caretakers or visitors
	Stretching	Stretching body and yawning
	Out of sight	Not visible to the observer or camera inoperative
	Self-play	Purposeful activity with self (e.g., rolling, tail-chasing) but not repetitive action or playing with food trays
	Aggression	Make aggressive physical contact with conspecific, typically including arching of tail and back, swatting, or biting
	Allogrooming	Licking another panda
	Response to another panda	Paying attention to conspecific
	Feeding from fecal tray	Feeding on feces and remaining undigested food from the fecal tray
Reproductive behavior	Sniffing	Sniffing urinated areas or feces
	Anogenital scent marking	Lifting tail and rubbing anus or genital area along the ground or an object; either in a sideways or front to back motion
	Mating	Male mounts the female and intromission occurs
	Chasing	Chasing the opposite sex
	Running	Running from the opposite sex

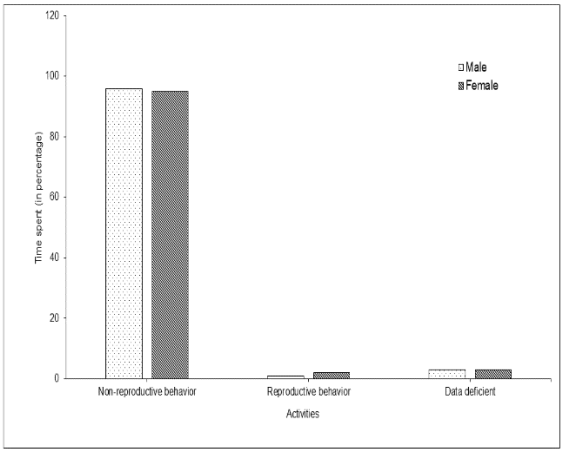

Figure 2 Non-reproductive and reproductive activities displayed by a male and female red panda based on scan sampling, Central Zoo, Kathmandu, Nepal, December 2020–July 2021.

Of the 15,701 events of male non-reproductive behavior, 37% (n = 5862; Figure 3) were sleeping, followed by locomotion (36%; n = 5639), resting (9%; n = 1413), feeding (9%; n = 1380), self-grooming (7%; n = 1102), and 2% (n = 305) on other behaviors. Of 15,643 female events, sleeping (51%) was the most common non-reproductive behavior (n = 7909), followed by resting (15%; n = 2361), locomotion (11%; n = 1775), feeding (11%; n = 1699), self-grooming (10%; n = 1623) and 2% (n = 276) on other behaviors.

Based on focal sampling, male and female non-reproductive activities comprised 19,663.7 min and 19,613.4 min of overall activity, respectively. The female slept most frequently (50.5% of the time), followed by resting (15.2%) on a log, tree branches, and sometimes the floor and in the nest box (Table 2, Figure 4). The male spent less time sleeping (39.1% of the time) and resting (7.8%). In contrast, the female spent more time feeding (11.7% of the time) and self-grooming (10.31%) than the male (8.7% and 6.5%, respectively). The male spent more time (36.0%) in locomotor behavior than the female (10.9%).

Among reproductive behaviors observed during scan sampling, the male scent marked on 41% of occasions (n = 99; Figure 5), followed by chasing the female (17%; n = 41), responding to the female (12%, n = 30), aggression (12%; n = 29), sniffing (7%; n = 16), and feeding from the fecal tray (7%; n = 16). The female spent 47% of the total number of reproductive events in responding to the male (n = 140), followed by allogrooming (15%; n = 46), running from the male (13%; n = 39), scent-marking (12%; n = 36), and aggressions (9%; n = 28).

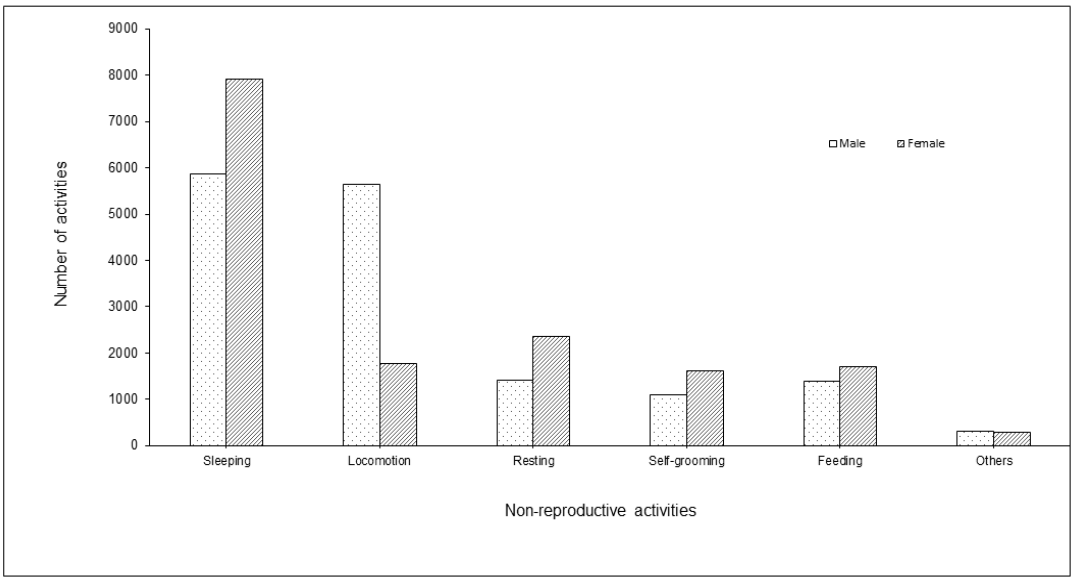

Figure 3 Non-reproductive activities displayed by a male and female red panda based on scan sampling, Central Zoo, Kathmandu, Nepal, December 2020–July 2021.

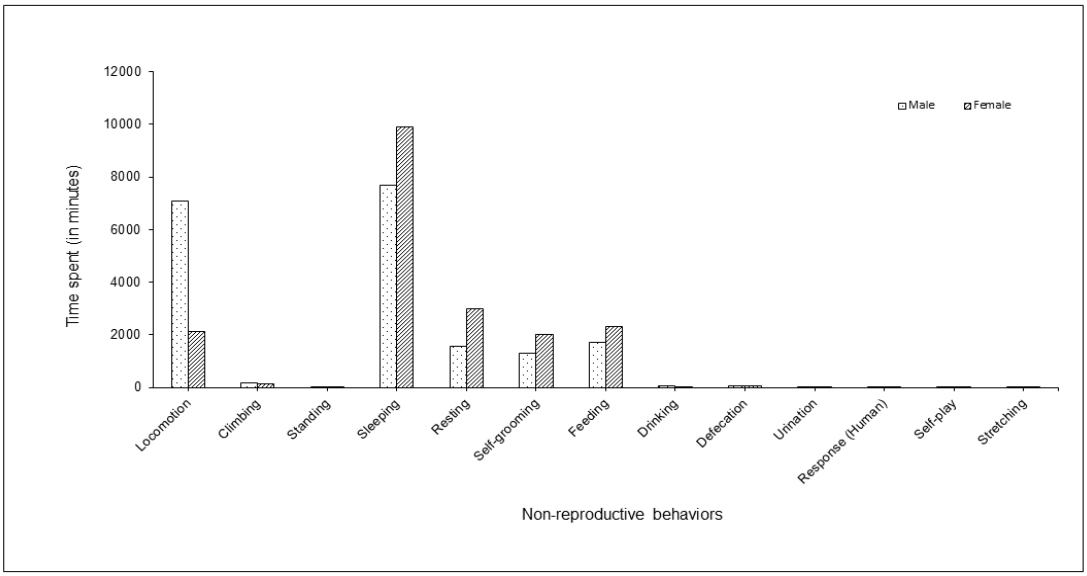

Figure 4 Non-reproductive activities displayed by a male and female red panda based on focal sampling, Central Zoo, Kathmandu, Nepal, December 2020–July 2021.

Table 2 Behaviors displayed by a male and female red panda, Central Zoo, Kathmandu, Nepal, December 2020–July 2021. Significant *P* values (<0.05) from Mann-Whitney U tests are in bold.

Variables	Median (Range)		*P-value*
	Male	Female	
Locomotion	40.99 (5.19 – 72.28)	9.47 (0.79 – 47.14)	<0.001
Climbing	0.79 (0.08 – 4.51)	0.43 (0.05 – 4.73)	0.001
Standing	0.00 (0.7 – 1.18)	0.00 (0.08 – 1.26)	0.281
Sleeping	44.77 (14.72 – 78.23)	60 (10 – 95.71)	<0.001
Resting	6.98 (0.25 – 32.59)	16.61 (1.6 – 46.6)	<0.001
Self-grooming	6.47 (0.48 – 30.69)	11.28 (0.75 – 28.44)	<0.001
Feeding	8.95 (0.57 – 27.07)	12.8 (0.2 – 37.44)	<0.001
Drinking	0.23 (0.05 – 1.6)	0.00 (0.12 – 1.17)	<0.001
Defecation	0.27 (0.08 – 1.32)	0.37 (0.1 – 2.11)	0.002
Urination	0.00 (0.05 – 0.27)	0.00 (0.02 – 0.18)	0.251
Response (human)	0.00 (0.12 – 1.53)	0.00 (0.08 – 1.38)	0.398
Self-play	0.00 (0.38 – 0.86)	0.00 (0.07 – 1.67)	0.412
Stretching	0.00 (0.03 – 0.13)	0.00 (0.05 – 0.25)	0.031
Aggressiveness	0.00 (0.03 – 0.69)	0.00 (0.05 – 0.65)	0.958
Response (conspecific)	0.00 (0.03 – 8.04)	0.38 (0.08 – 10.58)	<0.001
Sniffing	0.00 (0.05 – 2.68)	0.00 (0.07 – 0.54)	<0.001
Scent-marking	0.24 (0.03 – 2.87)	0.00 (0.06 – 2.21)	<0.001
Chasing	0.08 (0.02 – 1.27)	0.00 (0.04 – 0.47)	<0.001
Running	0.00 (0.04 – 0.48)	0.80 (0.04 – 1.27)	<0.001

We observed nine reproductive events (Table 2, Figure 5). The male spent 276.02 min, and the female spent 326.68 min of the total time budget on reproductive behaviors. The female spent 59.0% of the time responding to the male, while he spent 18.2% in response to the female. There was no variation in aggressive behavior exhibited between individuals ($P > 0.05$; Table 2, Figure 6), which led to chasing and running between the pair. Chasing ($P < 0.001$; Table 2) and running against each other ($P < 0.001$; Table 2) behaviors revealed a considerable difference between the sexes. The male chased the female more often ($P < 0.001$), representing 11.8% of his total time spent on reproduction compared to 1.3% of the female's time chasing the male. In contrast, 1.6% of the male's time and 8.8% of the female's time was invested running from the other.

4. Discussion

The red pandas exhibited reproductive behaviors at the Central Zoo even though the zoo is outside the species' geographic range. Multiple copulations suggest the Central Zoo could consider establishing a red panda breeding center. The male red panda was more active overall than the female, who spent considerable time sleeping and resting, while the male spent most of his time in locomotion and climbing. The difference in the frequency of behaviors might have occurred as the pair tried to avoid each other at the start of the study. Following an initial introduction, animals often exhibit mutual tolerance through avoidance (Roberts and Kessler 1979). Animals also establish distinct resting and sleeping locations to maintain separation (Roberts and Kessler 1979). As the pair were confined in the male enclosure, the preference for the ground by the male may indicate an attempt to dominate the larger area and exhibit territoriality. Males patrol their regions more than females (Spiezio et al 2022). The male may also have spent more time on the ground waiting for the female to access the ground for mating; most carnivores, including red pandas, engage in copulation on the ground (Roberts and Gittleman 1984).

The female in our study spent more time feeding than the male, who may have been exhibiting dominance-related behavior during the breeding season. Females can dominate reproductive behavior and social interactions in some species (e.g., martens [*Martes Americana*]; (Heath et al 2001). When food was offered at the beginning of being housed together, the female would chase the male away and feed alone. Although food sharing and feeding near began within a few

days, and there was no fighting over food, the male still displayed less feeding. The female increased feeding occurrences when more food was available, in contrast to giant pandas (*Ailuropoda melanoleuca*), where males spend more time feeding than females (Mainka and Zhang 1994; Liu et al 2003).

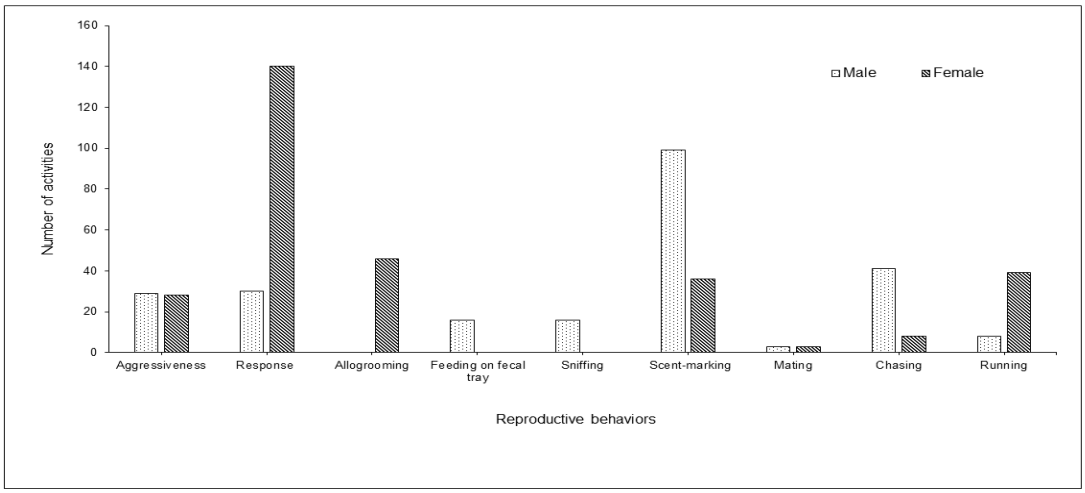

Figure 5 Reproductive activities displayed by a male and female red panda during scan sampling, Central Zoo, Kathmandu, Nepal, December 2020–July 2021.

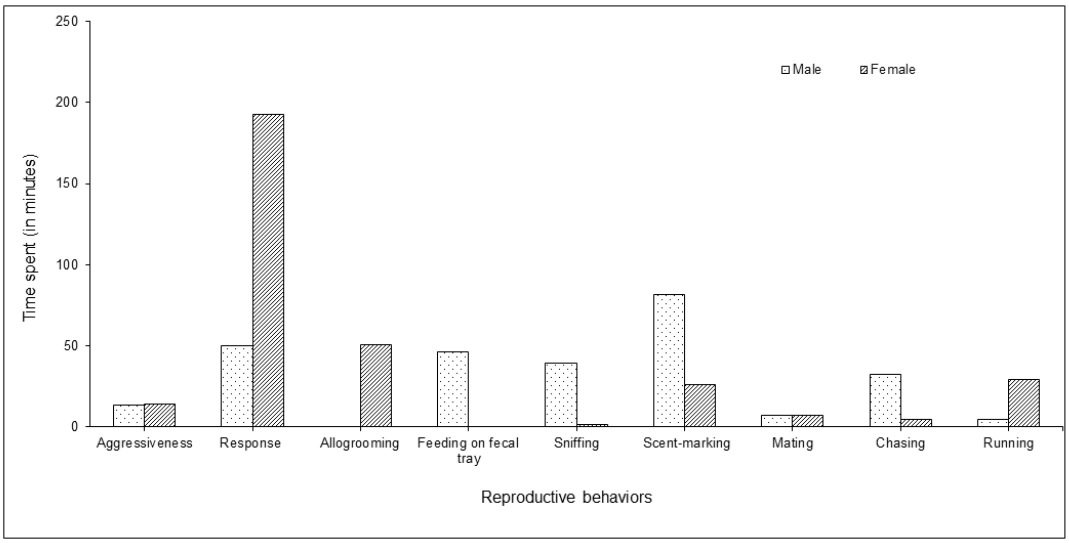

Figure 6 Reproductive activities displayed by a male and female red panda based on focal sampling, Central Zoo, Kathmandu, Nepal, December 2020–July 2021.

We did not observe stereotypic behavior, which often includes repeated pacing and self-harm (Tepper et al 1999; Swaisgood et al 2001; Meagher et al 2014). This might be because the animals were in favorable conditions with an air-conditioned structure that afforded security from disturbances, a large outdoor enclosure, and readily available food. Captive animals display less stereotypic behavior when housed in sufficient spaces with proper nutrition and enrichment (Molla et al 2011; Antonenko et al 2019). Further, housing solitary animals in pairs has benefitted other carnivore species and reduced atypical behaviors (Duncan 1998; Swaisgood and Shepherdson 2005; Spiezio et al 2022).

Within a few weeks of introduction, the male carefully observed the female's actions and made multiple attempts at copulation. The female would become agitated, resulting in either chasing or fighting. Reduced levels of female reproductive behavior are related to a short estrus, as observed in giant pandas (Kleiman 1983; Platz et al 1983; Swaisgood et al 2003).

Scent marking, primarily rubbing the anogenital region against ground and logs, was the most prominent reproductive behavior displayed by the pair, and urine marking was not observed. This was potentially an artifact due to the daily cleaning of the enclosure to maintain hygiene. As reported previously, more scent-marking events are displayed by the male than the female (Conover and Gittleman 1989). Mammalian carnivores frequently exhibit scent-marking to determine identity, reproductive status, spatial information, and communication (Peters and Mech 1975; Henry 1977; Mech 1977; Gosling 1982; Conover and Gittleman, 1989; Gorman and Trowbridge 1989). Female

marking may communicate increasing receptivity to males and contribute to increased sexual activity in males (Heath et al 2001).

The female showed a high level of grooming and an exclusive display of allogrooming. Females often use grooming to strengthen social relationships (Henazi and Barrett 1999). The female was regularly observed grooming the male while sleeping. Allogrooming in solitary species is typically observed only during the breeding or rearing of young and facilitates courtship, bonding, cleanliness, and social rank (Sachs 1988; Smolinsky et al 2009; Ishii et al 2017).

Red pandas in this study were habituated to defecate in fecal trays provided but defecated in other areas after being placed together. The male was observed feeding on fecal matter, which to our knowledge, has not been previously reported. This behavior could represent an extreme display of chemo-communication due to the presence of hormones in the feces, comparable to other reproductive behaviors like sniffing feces and licking scent-marked areas during the breeding season. It could also be due to the deprivation of females and reduced opportunity to display sexual behavior; tortoises, insects, and humans relieve sexual tension through atypical behaviors like onanism, same-sex sexual behaviors, or interspecific sexual practices (Bonnet et al 2016; Sales et al 2018). Nevertheless, three successful mating events occurred during the study before which feeding activity was reduced, and they rested closer to each other for longer periods during the day. During copulation, the male mounted the female and clasped her by the abdomen with the occasional licking of the neck and shoulders, as reported previously (Roberts and Gittleman 1984).

We are uncertain why parturition did not occur. We noted both red pandas had heavy flea infestations, which in carnivores can cause increased stress, adversely affect health, and result in infanticide (Loeffler 2011; Sundell 2003). Another reason for failed reproduction could be the proximity of captive golden jackals *Canis aureus* at the zoo, a potential predator of red pandas. Management guidelines suggest red panda enclosures should be $\geq$ 50 meters from those of large predators (Glatston 1989). The red panda exhibit next to the golden jackals could have resulted in chronic stress and associated impaired immunological and reproductive function (Terio et al 2004; Mason and Rushen 2008; Eriksson et al 2010). More extensive research of factors including mate compatibility and choice, individual reproductive capacity, quality of care offered, stress levels, diet, and health are necessary to improve red panda captive breeding programs.

5. Conclusions

This study provides detailed information on the behavior of the red pandas in captivity during the breeding season in the Central Zoo of Nepal. The female showed more inactive behaviors like sleeping and resting, while the male spent more time on locomotion. Additionally, the female exhibited higher levels of feeding and self-grooming behaviors than the male. The male showed more sexual activity and spent most of his time on anogenital scent marking. Copulation was observed three times during the entire study period, and the reproductive behavior was negatively affected by precipitation. These findings provide valuable insights into the reproductive behavior of red pandas in captivity, which could aid in developing effective conservation strategies for this endangered species.

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Ethical considerations

Data for this research was collected without handling or disturbing animals, so ethical permission for animal handling animals was not required.

Conflict of Interest

The authors declare no conflict of interest.

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