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Social Behaviour and Distance during Maternal Care in captive Red Panda (*Ailurus fulgens*)

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Contents

1. Abstract

This study examined the social behaviour and distance of a captive mated red panda pair and their cub during maternal care, and the impact of external variables such as the visitors' presence, temperature and feeding routine on their behavior. Scan sampling at two-minutes intervals was used to record individual behaviour and inter-individual distance. Resting and moving were the most frequent behaviours, followed by eating and alert. Alert was more frequently performed by the female, likely due to the cub. Resting was negatively correlated with time for the adults suggesting that they preferred to rest in the sunshine as the weather was getting cloudier as time went by. Aggression from the male towards its offspring increased across the observation period, as well as their physical proximity. Peak activity rate corresponded to the feeding routine, and mealtime change increased the frequency of natural behaviours. As solitary animals, the individuals were mostly far from each other, but the mother and cub very close or touching. In the presence of visitors, the activity rate of the red pandas was significantly higher, however they were also regularly enriched when the zoo was open. The female's activity rate was correlated with ambient temperature, but this is more likely related to the cub's growth. The present study provides new perspectives into the social distance and behaviour during maternal care in captive red pandas and suggests new ways to improve the captive red panda's welfare.

Keywords: Red pandas, Maternal care, Activity budget, Social distance, External variables, Enrichment, Captive animals, Welfare

2. Introduction

The red panda (*Ailurus fulgens*) is a member of the mammalian order Carnivora. Within this order, they are one of the five known species of obligate bamboo eaters (Yonzon & Hunter, 1989). *Arundinaria* species, commonly known as bamboo, belongs to the grass family *Poaceae*. Consumed during all seasons, bamboo comprises almost 80% of the red panda diet (Panthi et al., 2015; Roka et al., 2021; Wei et al., 1999; Yonzon, 1989). The red panda lives in subtropical and temperate forests between 2500 m and 4800 m above sea level (ASL). It selects habitat with high density of fallen logs, shrubs (to have an easy access to bamboo) and bamboo culms that correlate with steep slopes. A close source of water is an essential element of the habitat as well (Thapa et al., 2018; Wei et al., 2000, 2022).

This species is classified as Endangered by IUCN as its population decreased by 50% in only 18 years and is expected to decrease more in the years to come (Glatston et al., 2015). As part of the global conservation efforts and one of the priority actions for this species according to IUCN, zoos have an important role to play. Besides providing a safe place for the animal, they are educators by raising awareness about the species, its habitat, behaviours, and threats in the wild. In that duty, zoos are responsible and expected to offer the best conditions possible to fulfill the animal's welfare and well-being needs.

In the wild, red pandas rest most of the day, around 15 hours per day, in periods of less than 4 hours (with short rest, less than 1 hour; mid-length rest, between 1 and 2 hours; and long rest, more than 2 hours) separated by frequent activity periods (Frilot & Medved, 2014; Wei et al., 2022). The frequency and duration of the long rest does not change much between seasons, except in winter. In fact, in winter, the frequency of rest increases which may be linked to the need of conservation of heat and hence reduction of metabolism (Wei et al., 2022). Most studies state that red pandas are more active during the day. For the six red pandas studied at the Fengtongzhai Reserve, 44.8% of the activity period was in the daytime, 30.2% at dawn and dusk, only about 25.0% at night (Wei et al., 2022).

In captivity, due to human care, red pandas are more active during daytime with two activity peaks, one in the morning between 7:30 and 11:00, and one in the late afternoon between 16:00 and 19:00 (Bugler, 2021; Han et al., 2005). These peaks vary according to the feeding routine of each zoo. Bugler (2021) studied the activity budgets of red pandas of three different zoos. With all zoo data combined, sleeping was the most common behaviour observed confirming Gebauer's

(2022) results, followed by locomotion and grooming as the second and third most frequently performed behaviours, respectively (Bugler, 2021). It is known that the wellbeing and behaviour of captive animals can differ in the presence of visitors and fluctuation of the temperature. It was also found in captive red pandas that the activity pattern varies according to the presence of young red panda cubs (Khan & Baskaran, 2019).

When comparing the activity budget of captive and free-ranging red pandas, they are more active in the wild, likely due to foraging needs. In addition, Glatston (2022) stated that because "captive diets do not occupy enough of the red panda's daily activity, pandas may compensate for this activity "vacuum" by over-grooming and eating hair.". Similar comparisons of activity budgets between captive and free-ranging animals in other mammal species did not show any major variations (Giant panda: Zhang et al., 2015) (Giraffes: Bashaw, 2011) (Sulawesi crested black macaques: Melfi & Feistner, 2002) (Boars: Blasetti et al., 1988).

Little is known about maternal behaviour, mother-cub interaction and even less about father-cub and father-mother interaction during the growth of the offspring. Red panda cubs have a slow development and reach maturity between 18 and 20 months of age (Curry, 2022). When the cub starts to leave the den (in the wild) or nest box (in captivity), after 3 months (Northrop & Czekala, 2011), the female's time allocation to behaviours changes, likely associated with the development of the cub, as it becomes more independent to groom and thermoregulate self (Dechanupong, 2019).

It was therefore the aim of the present study to better understand the activity budget of captive red pandas to improve their welfare and obtain a baseline for future ideas about environmental enrichment, the distance of a mated pair and their cub during the first months of the cub's life, and the impact of external variables such as the visitors' presence and temperature.

3. Materials & Methods

3.1. Animals

The study included three red pandas (*Ailurus fulgens*) maintained at Borås Djurpark in Sweden: a mated pair (Shifu: nine-years-old male, and Wanju: seven-years-old female) and their three-months-old female offspring (Laya, born on June 24th, 2022) (Figure 1). They were housed in a complex of two outdoor enclosures (called back and front enclosure, respectively), two temperature-controlled houses, and 3 small houses placed in the front enclosure (Figure 2). At the beginning of the study, the offspring was not moving independently outside the houses and indoor areas, it started to do so during the second week of data collection (Monday, October 3rd: first time observed out, unsteady). During the data collection, bamboo and berry plants were planted in the outdoor enclosures.

Figure 1: The studied red pandas, from the left to the right: Shifu, Wanju, and Laya.

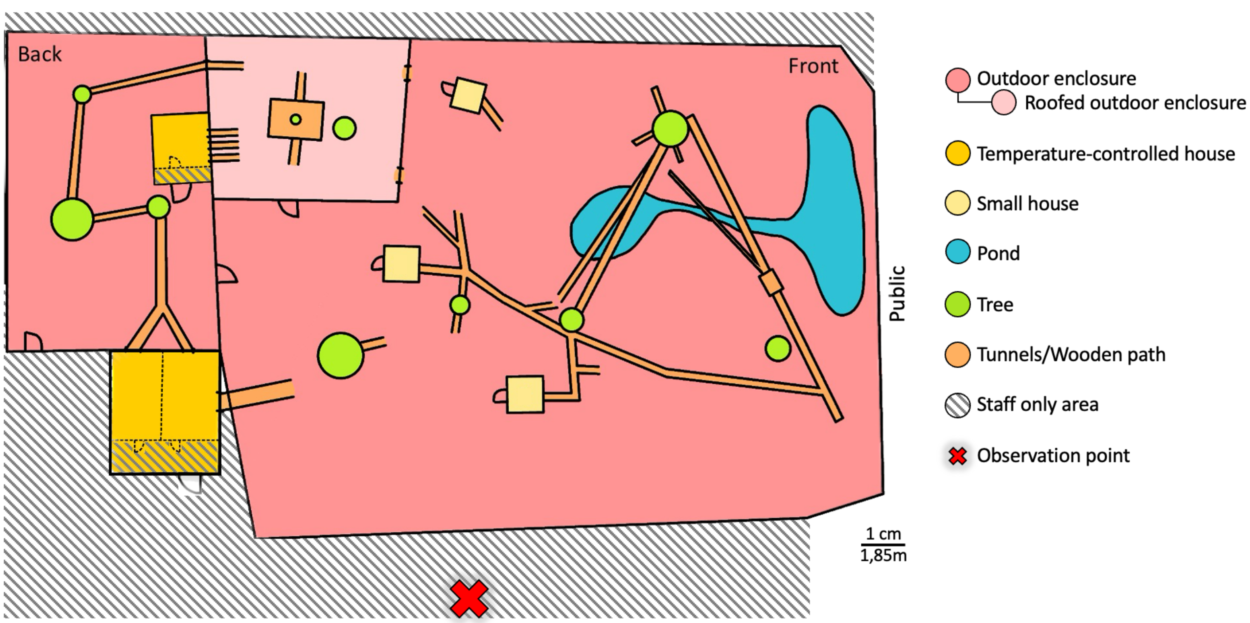


Figure 2: Schematic drawing of the red pandas' enclosure at Borås Djurpark.

3.2. Experimental procedure

Observations were recorded from outside the enclosures, where the front enclosure and part of the back one were visible (Figure 2), using scan sampling at two-minutes intervals. The red pandas were observed 4 hours per day between 8:30 am and 5:00 pm, 5 times per week, for 10 weeks (September 2022 - December 2022).

The ethogram used in this study was based on previous studies (Jule, 2008) and consisted of 13 behaviours (Table 1). Distance between individuals was recorded into four categories chosen to better understand the close dynamics of red pandas (Table 2). During the data collection, I determined each category with an approximate distance basing myself on the elements of the enclosure, because distances could not be approximated any better than this, due to physical challenges.

Table 1. Ethogram of the red pandas observed in Borås Djurpark, Sweden, 2022.

Eating	Eating food: provisioned – fruits, vegetables, pellets – or browse – bamboo
Drinking	Drinking water
Resting	Lying (either curled in ball or lying flat out) - unresponsive to noise/activity
Moving	Moving along vertically or horizontally on or off the ground
Self-grooming	Grooming or scratching own body, not repetitively
Allo-grooming	Grooming or scratching a conspecific's body, not repetitively
Exploratory	Exploratory/territorial investigation of enclosure, can involve sniffing, digging, interaction with furnishings within enclosure
Alerting	Awareness and observation of surroundings
Food foraging	Foraging in enclosure (e.g., permanent trees, grass), can include digging
Playing	Purposeless activity such as rolling, tail-chasing, but not repetitive
Aggression	Anti-social interaction with conspecific
Out of sight	Unable to be seen by the observer

Table 2. Inter-individual distances of the red pandas observed in Borås Djurpark, Sweden, 2022.

Touching	Individuals touch each other
Very close	Individuals are approximately at less than 1 meter from each other
Close	Individuals are approximately between 1 and 5 meters from each other
Far	Individuals are approximately at more than 5 meters from each other

3.2.1. Zoo openings

The zoo was open for nine days during the study period. Six days out of these nine, the "red panda experience" occurred. The "red panda experience" enabled a maximum of four visitors to receive an information session from the zookeepers about their work with the red pandas and the importance of conserving them. Afterwards, the visitors had the opportunity to enter the enclosures and houses and give the red pandas their morning meal. It lasted 30 minutes and the visitors had close contact with the red pandas. When the "red panda experience" happened, the red pandas were fed at around 11:30, which is 2 hours later than when the "experience" does not occur.

3.3. Data analysis

3.3.1. Activity budget

The frequency of each behaviour was converted into proportions for each individual and for all three individuals combined:

$$\text{Behaviour X proportion} = \frac{\text{total occurrences of behaviour X in individual Y}}{\text{total occurrences of all behaviours in individual Y}} \qquad (1)$$

Based on that, binomial tests were conducted in RStudio (version 2023.03.0+386) with R (version 4.1.1) for each individual to assess whether a behaviour occurred significantly more frequently than the others.

Then the frequency of the most frequently displayed (*Resting*, and *Moving*) and cub growth-related (*Alert*, *Self-grooming*, *Exploratory*, *Food foraging*, *Playing*, and *Aggression*) behaviours were correlated with time (i.e., the observation weeks) using the Pearson correlation test.

To calculate the activity rates, all behaviours were regrouped into three categories: "Active" (all behaviours except *Resting* and *Out of sight*), "Inactive" (*Resting*), and *Out of sight*. Two ways were used: under- and over-estimation.

The underestimated activity rates take into consideration *Out of sight* and count it as "Inactive" because most of the time that the red pandas were *Out of sight*, they were inside and mainly sleeping, and occasionally grooming or eating:

$$\text{Underestimated activity rate} = \frac{\text{total occurrences of “Active” behaviours}}{\text{total occurrences of “Active”, “Inactive” behaviours and } \textit{Out of sight}} \qquad (2)$$

The overestimated activity rates do not include *Out of sight*:

$$\text{Overestimated activity rate} = \frac{\text{total occurrences of "Active" behaviours}}{\text{total occurrences of "Active" and "Inactive" behaviours}} \qquad (3)$$

3.3.2. Distance

Inter-individual distance was recorded into categories: *Touching*, *Very close*, *Close* and *Far* (Table 2).

Similar to behaviour, the frequency of each recorded distance category was converted into proportions for each individual and for all three individuals combined. Based on that, binomial tests were conducted to assess whether a certain distance category was significantly more frequent than the others.

After converting the distance categories into proportions for each week, a correlation with time (i.e., the observation weeks) was made using the Pearson correlation test.

To understand the relation between the behaviour *Aggression* and distance, the percentage of *Aggression* over all behaviours when Laya and Shifu were *Touching* or *Very close* was calculated:

$$\text{Aggression/distance relation 1} = \frac{\text{frequency of } \textit{Aggression} \text{ when Laya and Shifu were } \textit{Touching} \text{ or } \textit{Very close}}{\text{frequency of all behaviours when Laya and Shifu were } \textit{Touching} \text{ or } \textit{Very close}} \qquad (4)$$

and the percentage of *Aggression* that occurred when Shifu and Laya were *Touching* or *Very close* over all distances between all individuals:

$$\text{Aggression/distance relation 2} = \frac{\text{frequency of } \textit{Aggression} \text{ when Laya and Shifu were } \textit{Touching} \text{ or } \textit{Very close}}{\text{frequency of } \textit{Aggression}} \qquad (5)$$

3.3.3. Public

The activity rates of the animals were calculated using the same methods as described in 3.3.1., and a chi-square test was conducted to assess whether they differed depending on the presence or absence of visitors.

3.3.4. Temperature

As described in 3.3.1., the activity rate and the distances of each individual were correlated with the daily average temperature of Borås city. In addition, to understand if the assumptions behind the correlations were fulfilled, diagnostics were performed on the distances ones.

3.3.5. Red panda experience

The activity rate of the animals were calculated using the same methods as described in 3.3.1. and a chi-square test was conducted to assess whether they differed between days with and days without the "red panda experience", respectively.

To assess any consequences of the time-shift of the morning meal on the red pandas' behaviour, the proportions of each behaviour during the 30 minutes prior to the morning meal were compared when the red panda experience occurred and when not.

4. Results

4.1. Activity budget

The overall combined activity budget of the three individuals shows that the most frequently observed behaviours were *Resting* (34% of all interactions with a frequency of 1431/4223), *Moving* (27% of all interactions with a frequency of 1145/4223), *Eating* (14% of all interactions with a frequency of 568/4223) and *Alert* (10% of all interactions with a frequency of 402/4223) (Figure 3). All of these behaviours were significantly more frequent than the following less frequently observed behaviours (Binomial test: $p < 0.001$).

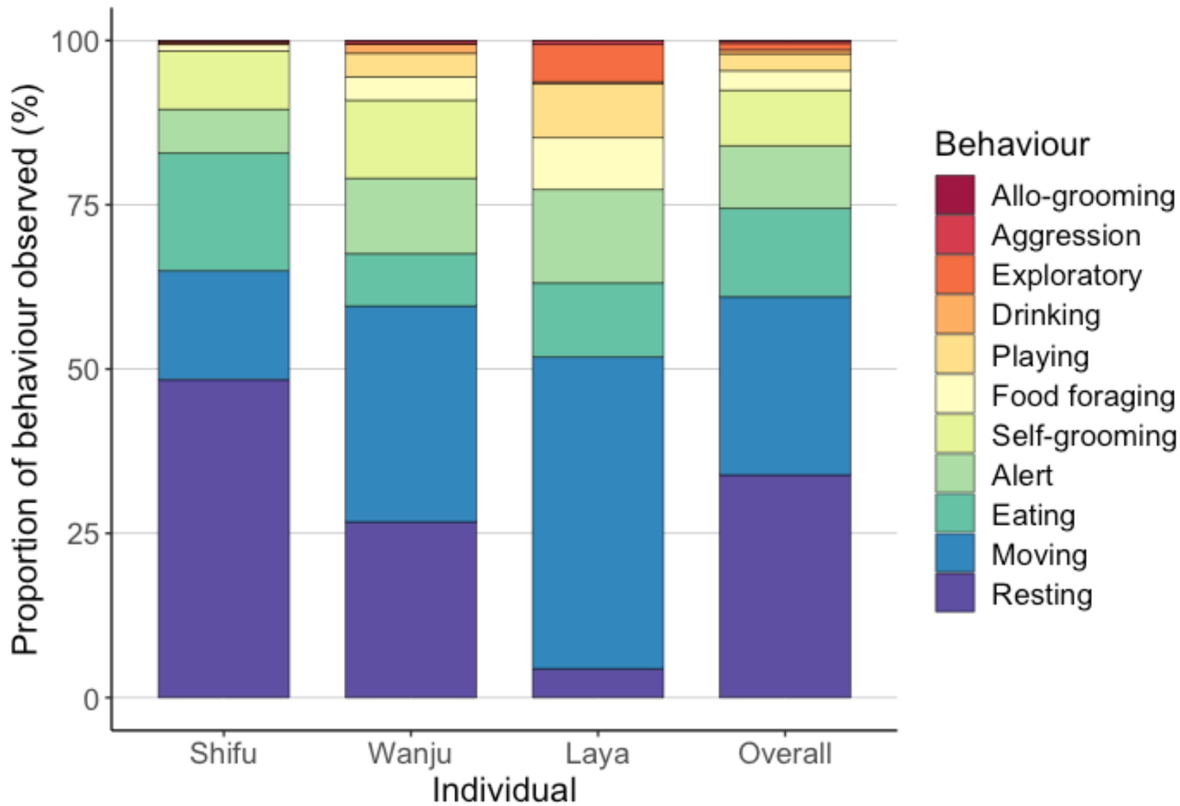


Figure 3: Activity budget across all three individuals combined (right column) and for each individual separately.

Shifu's (the adult male) most frequently observed behaviours were *Resting* (48% of all interactions with a frequency of 1016/2100), *Eating* (18% of all interactions with a frequency of 376/2100), and *Moving* (17% of all interactions with a frequency of 348/2100).

Wanju's (the adult female) most frequently observed behaviours were *Moving* (33% of all interactions with a frequency of 473/1440), *Resting* (27% of all interactions with a frequency of 385/1440), *Self-grooming* (12% of all interactions with a frequency of 171/1440) and *Alert* (11% of all interactions with a frequency of 165/1440).

Finally, for Laya (the female offspring), the most frequently observed behaviours were *Moving* (47% of all interactions with a frequency of 324/683) and *Alert* (14% of all interactions with a frequency of 97/683) (Figure 3). Here, too, each behaviour, mentioned above, were significantly more frequent than the less frequent behaviours (Binomial test, $p < 0.001$).

Overall, the red pandas were out of sight 77% of the time, and individually Shifu 66%, Wanju 76% and Laya 89% of the time.

Time-behaviour analysis shows that the most frequently displayed behaviour, *Resting*, was negatively correlated with time for Shifu and Wanju (Pearson correlation, Shifu: r = -0.71, Wanju: r = -0.70, p < 0.05), whereas *Moving* was not significantly correlated with time for any of the red pandas (Figure 4).

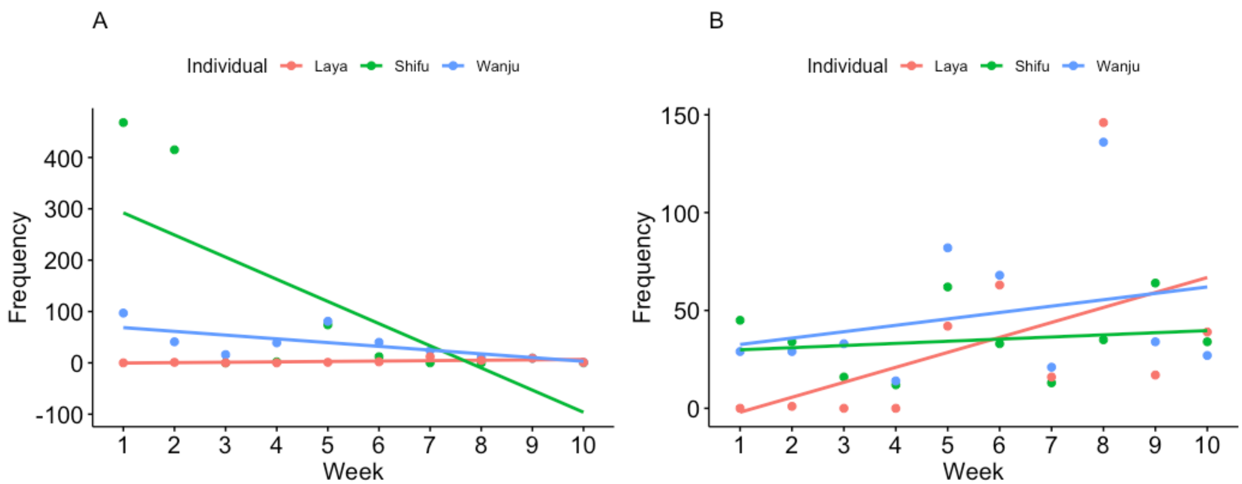
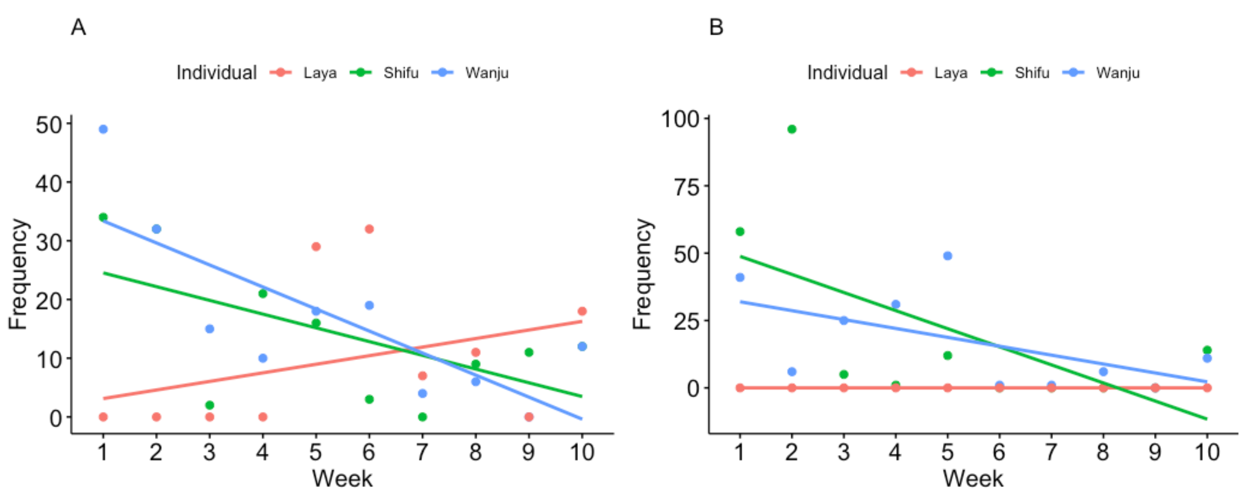


Figure 4: Correlation between the most frequently displayed behaviours and time.
(A) Resting; (B) Moving

Regarding cub growth-related behaviours, *Alerting* for Wanju and *Self-grooming* for Shifu were negatively correlated with time (Pearson correlation, Shifu: r = -0.63, Wanju: r = -0.78, p ≤ 0.05) (Figure 5A, B), whereas *Aggression* was positively correlated with time for Shifu (Pearson correlation, p = 0.06, r = 0.61) (Figure 5F).



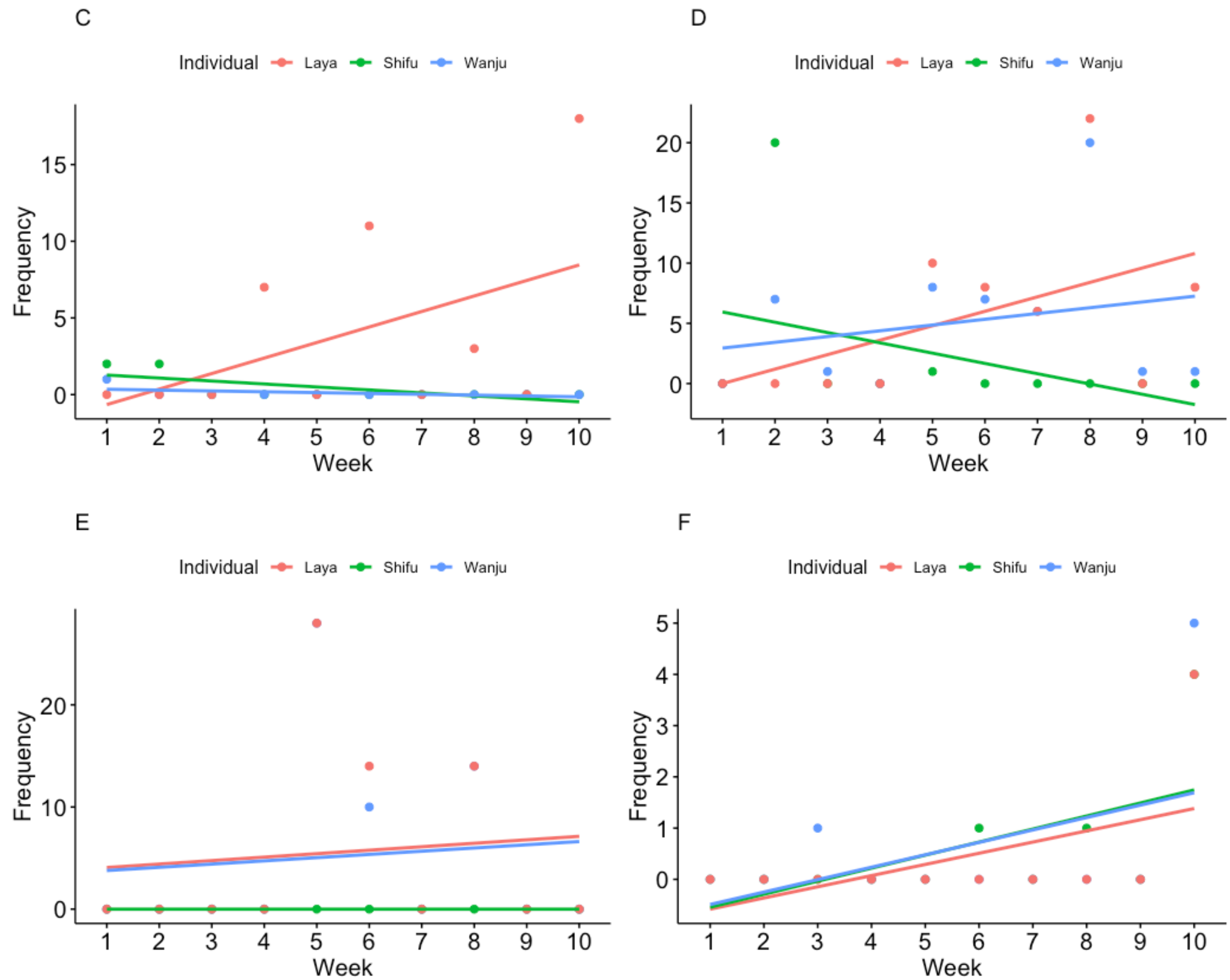


Figure 5: Correlation between the cub growth-related behaviours, and time.
(A) Alert; (B) Self grooming; (C) Exploratory; (D) Food foraging; (E) Playing; (F) Aggression

The daily hour-by-hour analysis demonstrates that, irrespective of whether the activity rate was underestimated or overestimated, the red pandas were mostly active between 9:30 and 10:00 (underestimation: 24.88%; overestimation: 91.24%), and 16:00 and 16:30 (underestimation: 29.41%; overestimation: 88.24%) (Figure 6).

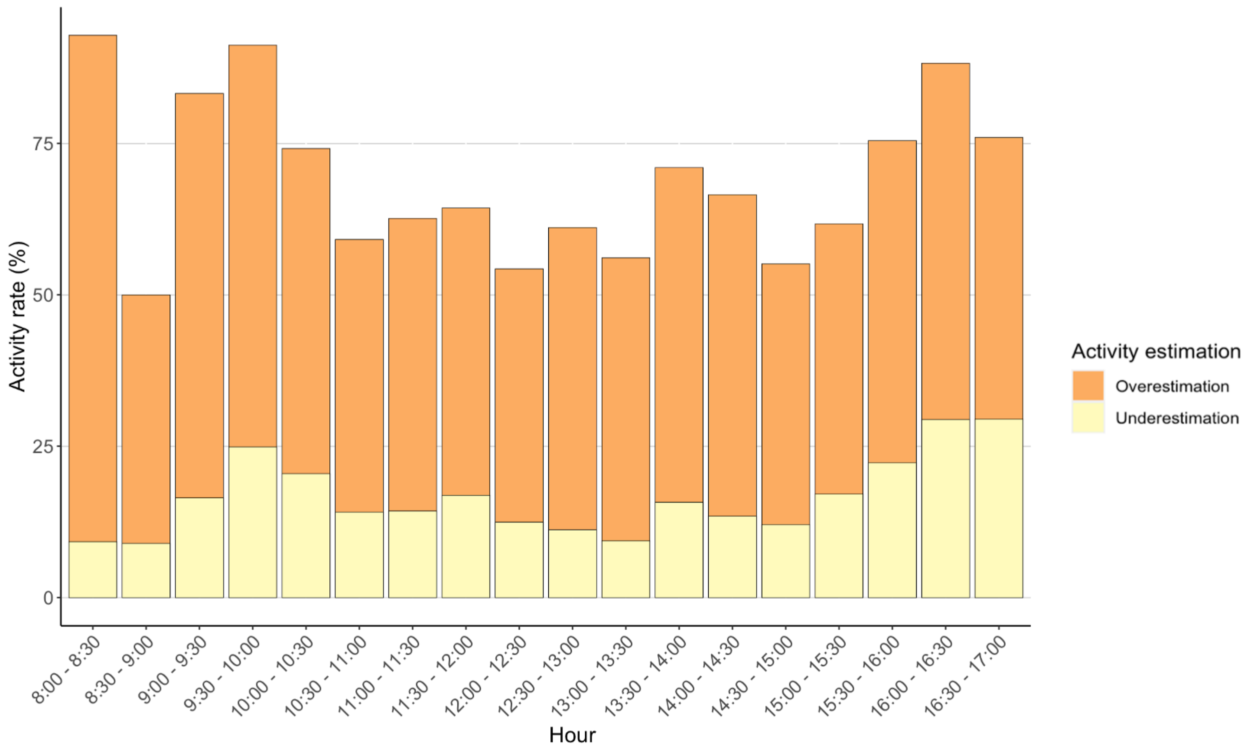


Figure 6: Hourly average activity rate across all animals combined.

4.2. Distance

When considering all three animals combined, the most frequently observed distance was *Far* (63% of all distance datapoints with a frequency of 11531/18327), followed by *Touching* (23% of all distance datapoints with a frequency of 4257/18327), *Close* (8% of all distance datapoints with a frequency of 1404/18327) and *Very close* (6% of all distance datapoints with a frequency of 1135/18327).

Between Shifu (the adult male) and Wanju (the adult female), the most frequently observed distance was *Far* (87% of all distance datapoints with a frequency of 5324/6109), followed by *Close* (9% of all distance datapoints with a frequency of 556/6109), and *Very close* (4% of all distance datapoints with a frequency of 229/6109). Shifu and Wanju were never recorded *Touching*.

The same ranking goes between Laya (the female offspring) and Shifu (*Far*: 87% of all distance datapoints with a frequency of 5332/6109, *Close*: 9% of all distance datapoints with a frequency of 539/6109, *Very close*: 4% of all distance datapoints with a frequency of 237/6109, and *Touching*: ~0% of all distance datapoints with a frequency of 1/6109).

At the opposite, between Wanju and her daughter Laya the most frequently observed distance was *Touching* (70% of all distance datapoints with a frequency of 4256/6109), followed by *Far* (14% of all distance datapoints with a frequency of 875/6109), *Very close* (11% of all distance datapoints with a frequency of 669/6109) and *Close* (5% of all distance datapoints with a frequency of 309/6109). All these distances were significantly more frequent than the following less frequent distances (Binomial test: $p < 0.001$)(Figure 7).

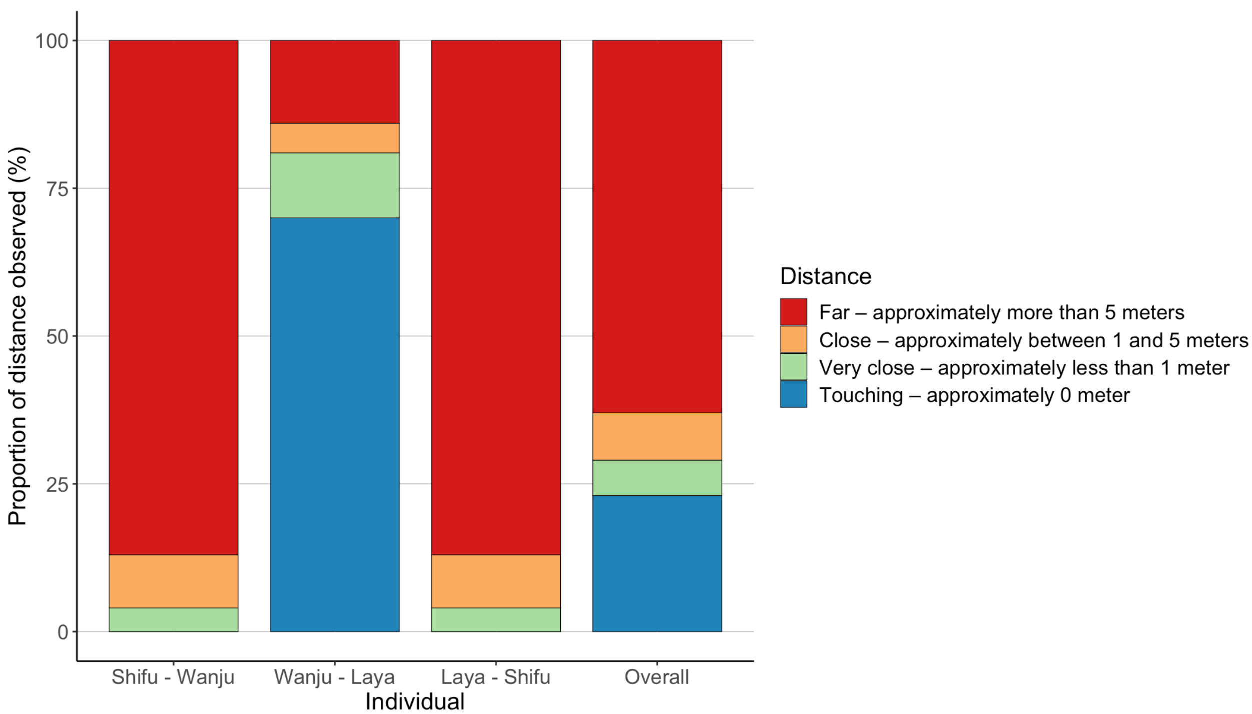


Figure 7: Proportion of distance across all three individuals combined (left column) and for each individual separately.

Distance and time were not significantly correlated between Shifu and Wanju (Figure 8). However, Wanju and Laya (Pearson correlation, *Far*: $r = -0.75$, *Very close*: $r = 0.82$, $p \leq 0.01$) (Figure 9B, D), as well as Laya and Shifu (Pearson correlation, *Very close*: $r = 0.70$, $p < 0.05$) (Figure 10B) were significantly closer from each other over the weeks.

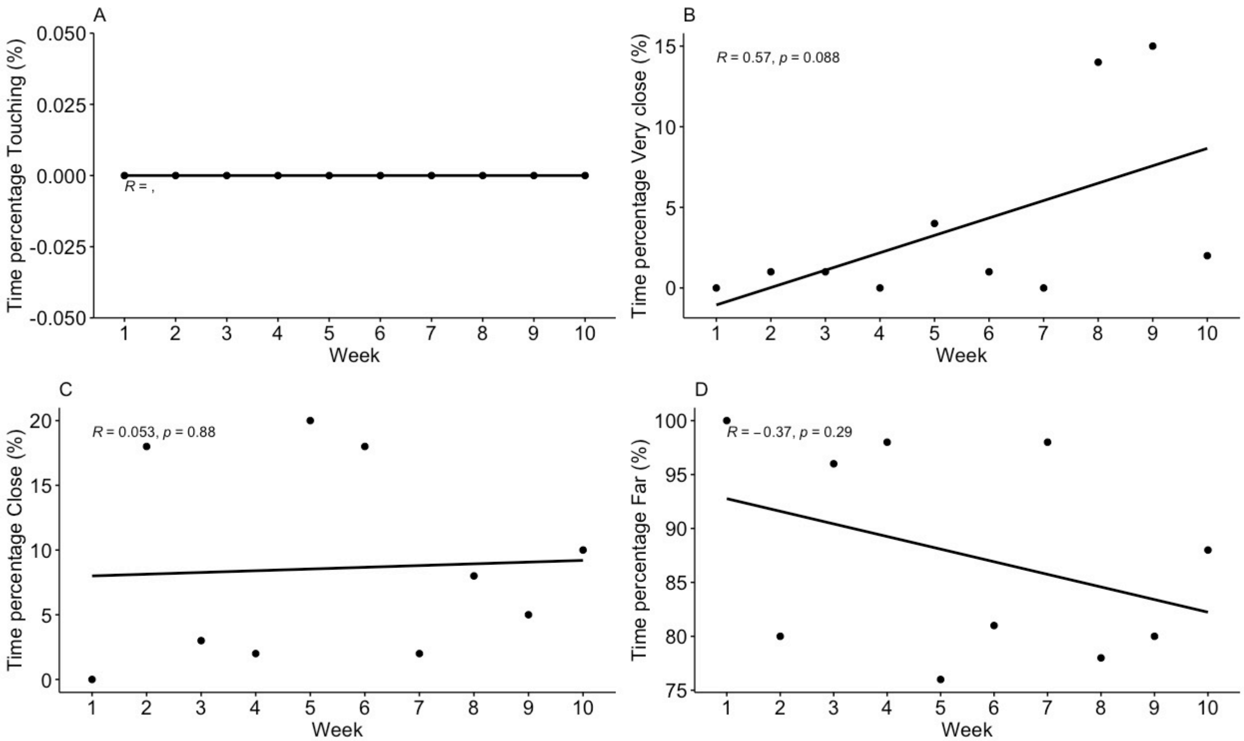


Figure 8: Correlation between the different distances between Shifu and Wanju, and time. (A) Shifu and Wanju *Touching* (approximately 0 meter); (B) Shifu and Wanju *Very close* (approximately less than 1 meter); (C) Shifu and Wanju *Close* (approximately between 1 and 5 meters); (D) Shifu and Wanju *Far* (approximately more than 5 meters)

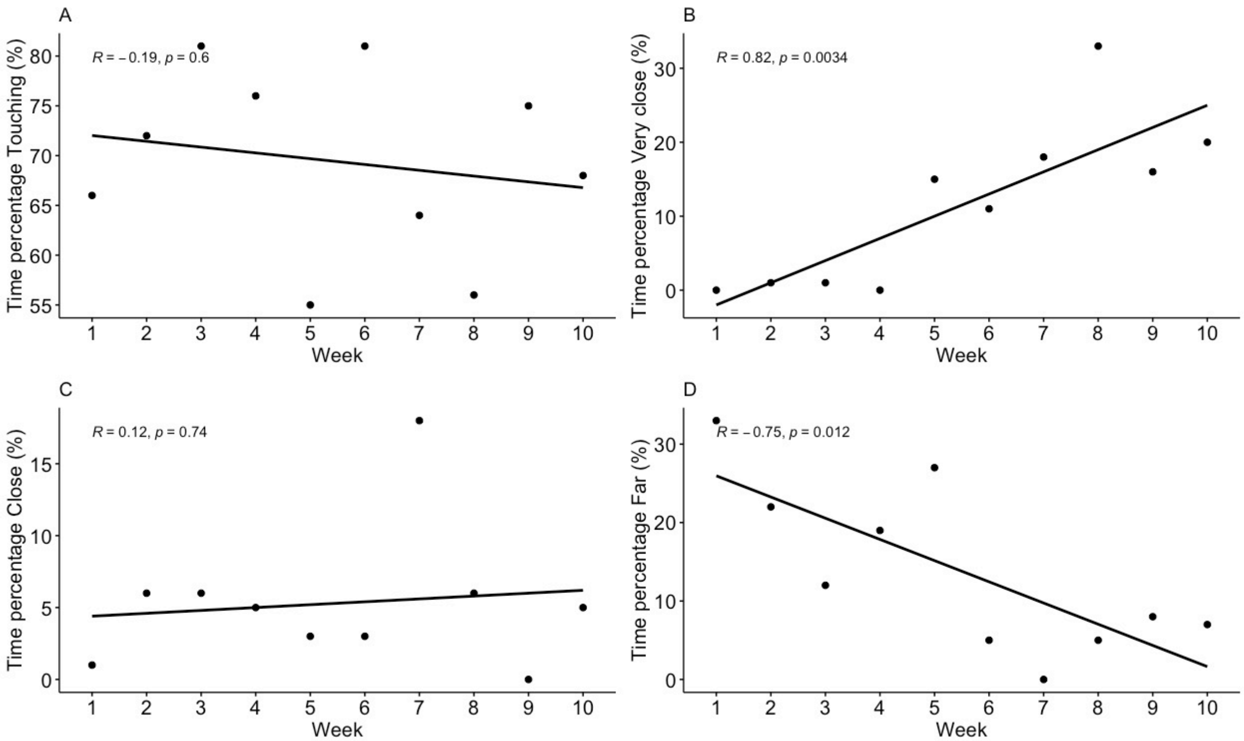


Figure 9: Correlation between the different distances between Wanju and Laya, and time. (A) Wanju and Laya *Touching* (approximately 0 meter); (B) Wanju and Laya *Very close* (approximately less than 1 meter); (C) Wanju and Laya *Close* (approximately between 1 and 5 meters); (D) Wanju and Laya *Far* (approximately more than 5 meters)

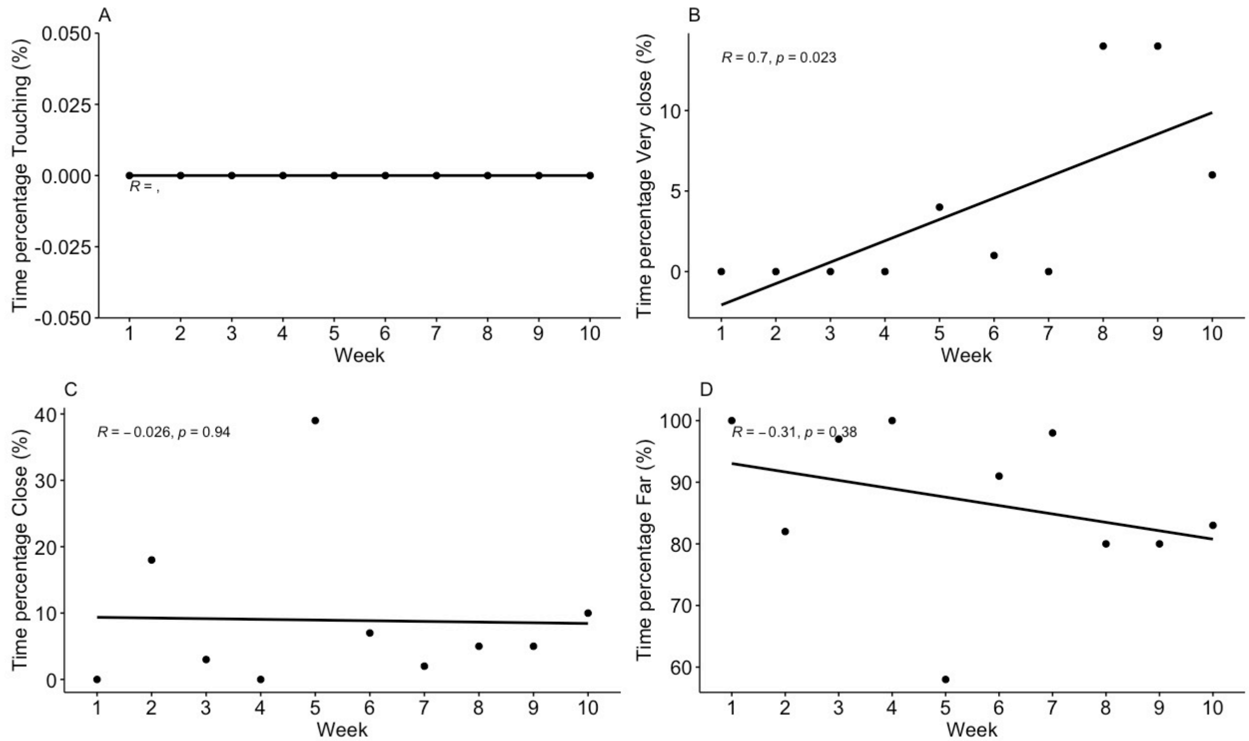


Figure 10: Correlation between the different distances between Laya and Shifu, and time. (A) Laya and Shifu *Touching* (approximately 0 meter); (B) Laya and Shifu *Very close* (approximately less than 1 meter); (C) Laya and Shifu *Close* (approximately between 1 and 5 meters); (D) Laya and Shifu *Far* (approximately more than 5 meters)

4.2.1. Aggression

The behaviour *Aggression* was displayed 15 times: 0 times when Laya and Shifu were *Touching*, 10 times when they were *Very close*, 2 times when they were *Close*, and 3 times when they were *Far* from each other.

When Laya and Shifu were *Touching* and *Very close*, 19% of their behaviours was *Aggression*. Out of all *Aggression* (across all individuals), 67% occurred when Laya and Shifu were *Touching* and *Very close*. In addition, most of the aggressions were observed at the end of the 10 week-period of the present study (Figure 11).

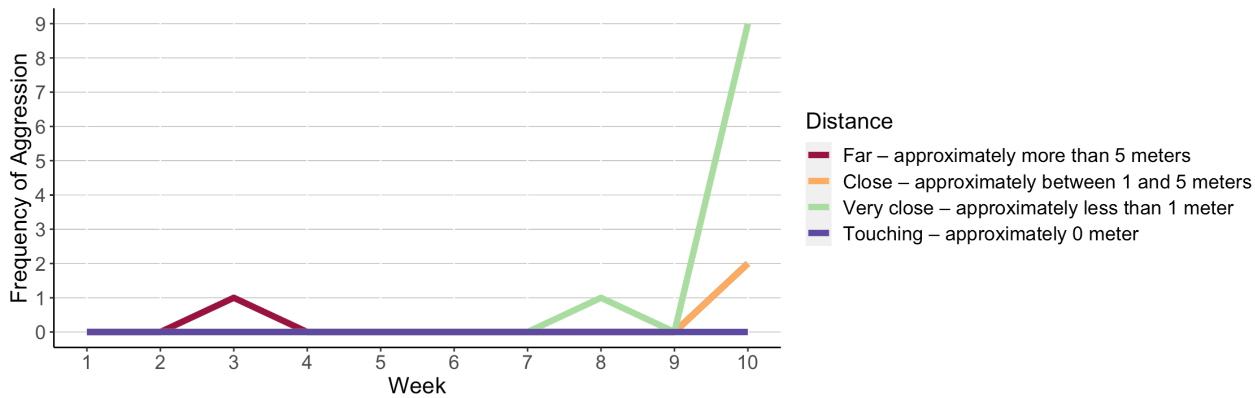


Figure 11: Frequency of *Aggression* per distance between Laya and Shifu per week.

4.3. Public

The activity rate was higher in the presence of public, and significantly differed from the activity rate displayed by the animals in the absence of public (Chi-square, $p < 0.01$). In addition, I found a shift of the morning peak hour from 9:30-10:00 to 10:30-11:00 (Figure 12).

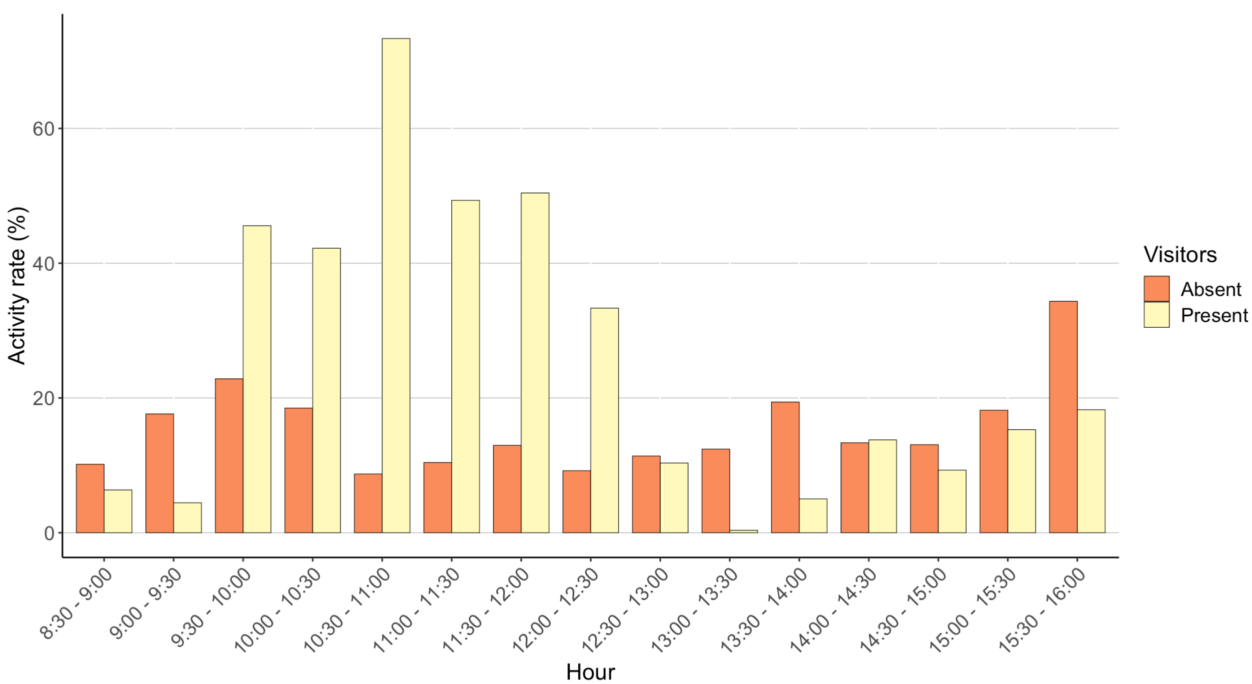


Figure 12. Hourly average activity rate with and without public

4.4. Temperature

The activity rate of Wanju (the adult female) significantly correlated negatively with temperature (Pearson correlation, r = -0.34, p < 0.05) (Figure 13C). This was not the case with all individuals combined (Figure 13A), neither individually for Shifu (the adult male, Figure 13B) nor for Laya (the female offspring, Figure 13D).

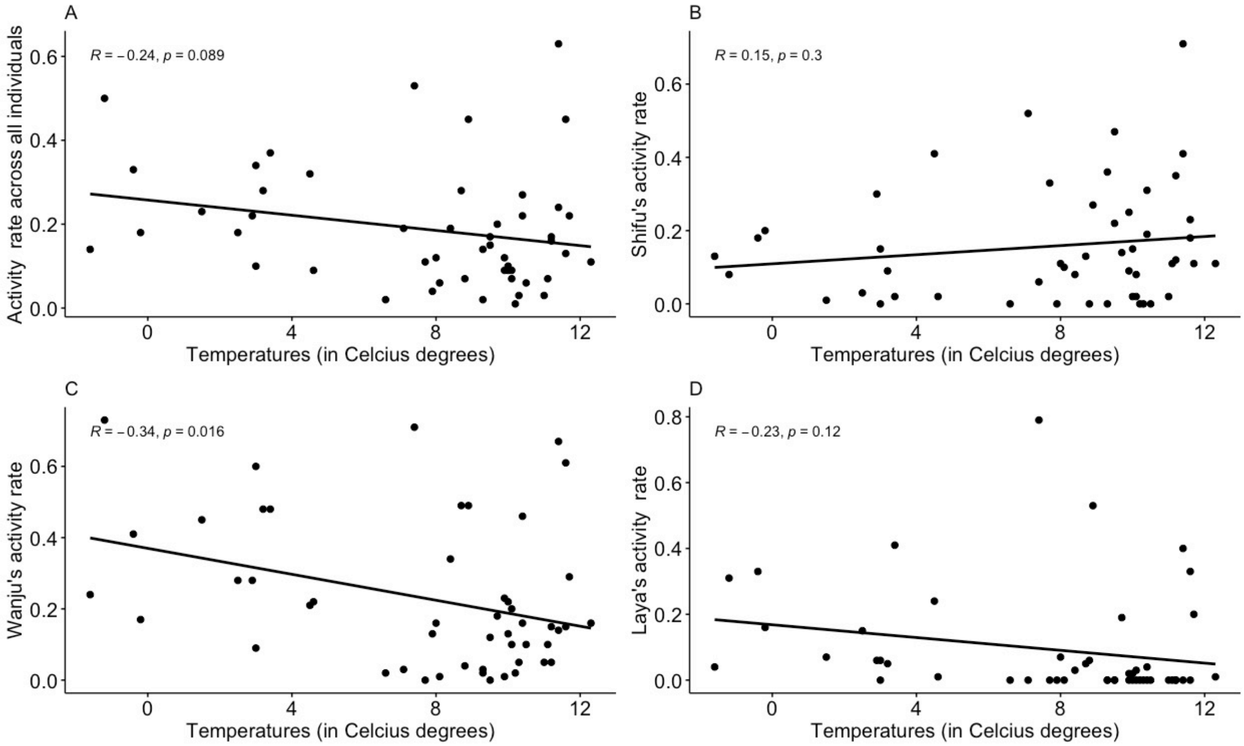


Figure 13. Correlation between activity rates and temperatures.
(A) Activity rate across all individuals; (B) Shifu's activity rates; (C) Wanju's activity rates; (D) Laya's activity rates

Similarly, Shifu and Wanju were more often *Very close* from each other in the end of observation (Pearson correlation, r = -0.53, p < 0.001) (Figure 14B), as the temperatures decreased. Alike, the distance between Wanju and Laya significantly correlated negatively with temperature (Pearson correlation, *Very close*: r = -0.34, p < 0.02) (Figure 15B). Finally, the same goes for the distance between Laya and Shifu (Pearson correlation, *Very close*: r = -0.58, p < 0.001) (Figure 16B). However, these results are hardly interpretable as the diagnostics showed that the residuals are not normally distributed meaning that the p-values are not accurate.

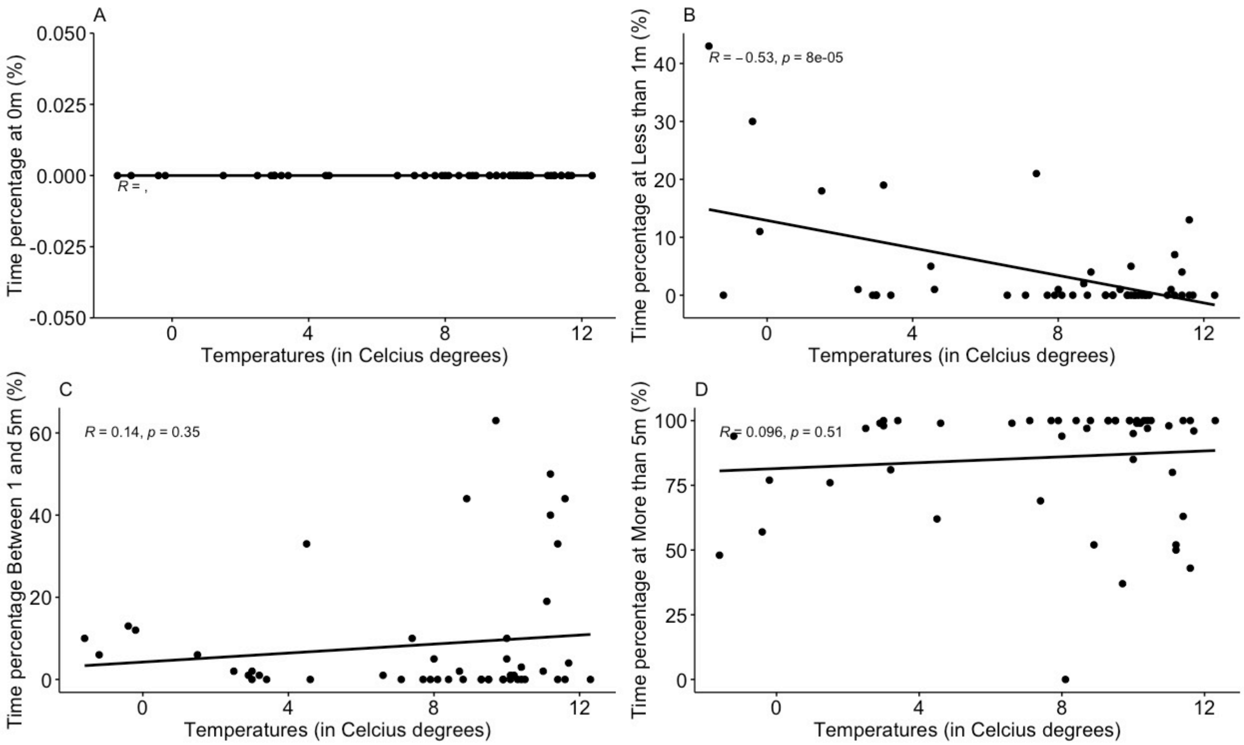


Figure 14: Correlation between the different distances between Shifu and Wanju, and temperatures.

(A) Shifu and Wanju *Touching*; (B) Shifu and Wanju *Very close*; (C) Shifu and Wanju *Close*; (D) Shifu and Wanju *Far*

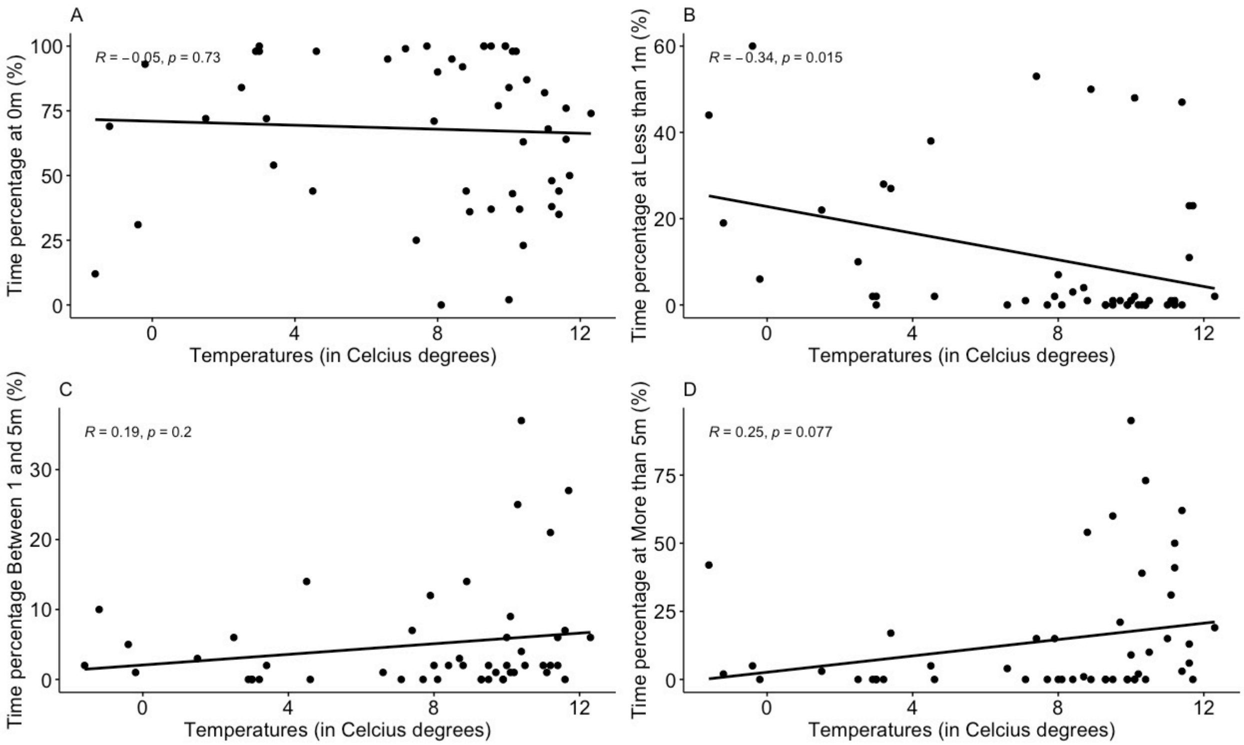


Figure 15: Correlation between the different distances between Wanju and Laya, and temperatures. (A) Wanju and Laya *Touching*; (B) Wanju and Laya *Very close*; (C) Wanju and Laya *Close*; (D) Wanju and Laya *Far*

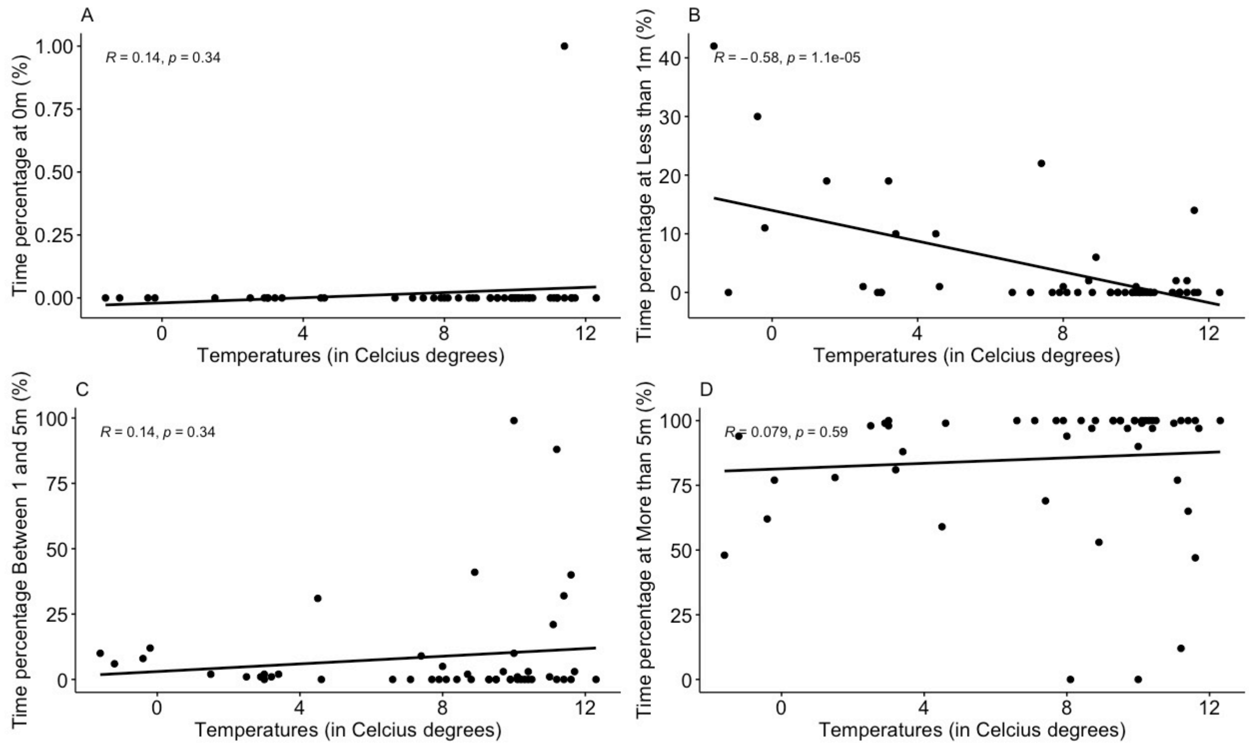


Figure 16: Correlation between the different distances between Laya and Shifu, and temperatures. (A) Laya and Shifu *Touching*; (B) Laya and Shifu *Very close*; (C) Laya and Shifu *Close*; (D) Laya and Shifu *Far*

4.5. Red panda experience

The red pandas' activity rate during the "red panda experience" was significantly higher than the one during normal days (days without "experience") (Chi-square test, $p < 0.01$).

With the "red panda experience", one additional behaviour was observed during the 30 minutes prior to the morning meal: *Playing* (12% of all interactions during the 30 minutes prior to the morning meal with the "red panda experience", with a frequency of 28/240). In addition, 5 behaviours were more frequently observed on days with the "red panda experience": *Aggression* (～0% of all interactions without the "red panda experience", with a frequency of 1/912; vs 1% of all interactions with the "red panda experience", with a frequency of 3/240), *Exploratory* (～0% of all interactions without the "red panda experience", with a frequency of 1/912; vs 2% of all interactions with the "red panda experience", with a frequency of 4/240), *Alert* (4% of all interactions without the "red panda experience", with a frequency of 35/912; vs 7% of all interactions with the "red panda experience", with a frequency of 16/240), *Food foraging* (1% of all interactions without the "red panda experience", with a frequency of 9/912; vs 3% of all interactions with the "red panda experience", with a frequency of 6/240), and *Moving* (11% of all interactions without the "red panda experience", with a frequency of 96/912; vs 25% of all interactions with the "red panda experience", with a frequency of 59/240)(Figure 17).

Finally, the red pandas were out of sight 45% of the time on days with "red panda experience", whereas they were out of sight 76% on normal days.

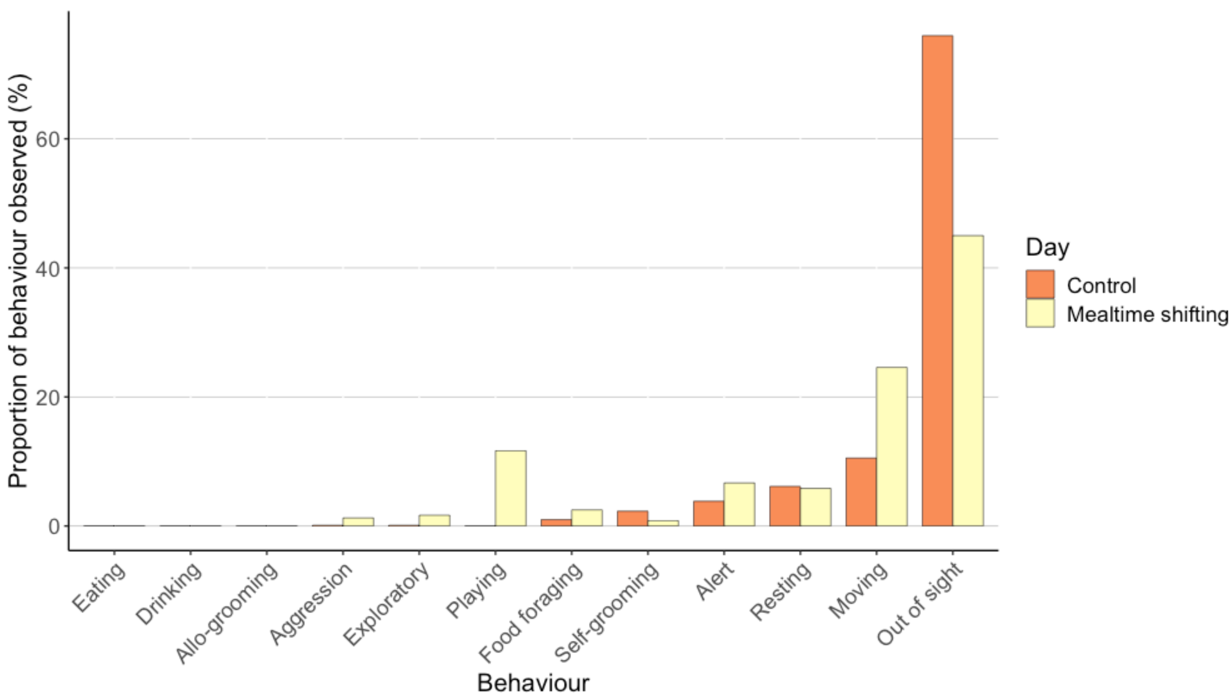


Figure 17: Percentage of displayed behaviour 30 minutes before the morning meal during non-red panda experience days and red panda experience ones.

5. Discussion

The present study investigated the social behaviour and distance of a mated red panda pair and their cub from its 3rd to 5th month of life, and the impact of external variables such as the visitors' presence and temperature on their behaviour. The most frequently displayed behaviours (*Resting* and *Moving*) and the correlations between cub growth-related behaviours and time are in line with previous studies. The peak activity rate corresponded to the feeding routine and shifted accordingly when the routine differed. Changes in distances between the individuals were linked to the cub's growth. The activity rate and one category of distance correlated with ambient temperature, but it is more likely that this was related to the cub maturing than the actual temperature. As for the impact of the visitor's presence, the red pandas' activity rate was significantly higher than when the zoo was closed. Finally, the "red panda experience" elicited a higher frequency of natural behaviours such as *Food foraging*, *Alert* and *Exploratory* before the meal compared to normal days. This suggests that changing the morning mealtime may benefit the captive red panda's welfare.

In my study, *Resting* and *Moving* were the most frequently observed behaviours which corroborates Bugler's (2021) study, followed by *Eating* and *Alerting*, respectively. *Resting* was not frequent for the cub probably because it mainly stayed in the den at this age, where it was not visible. Similarly, *Self- and Allo-grooming* were behaviours mainly displayed in the houses and therefore not visible, however they have been reported to be the third most frequently performed behaviour in captive red pandas (Bugler, 2021). The mother was more frequently *Alert* than the male likely because of the cub, as the enclosure of the red pandas studied here was less than 1 meter from the outdoor enclosure of spotted hyenas (*Crocuta crocuta*). According to management guidelines, red panda enclosures should not be close to aggressive animals and large carnivores (Glatston, 1989). Additionally, during the period of data collection, the zoo's spotted hyenas were having social issues, leading to loud fights including barks. The red panda mother was very sensitive to those vocalisations and always climbed to the highest point and was alert. Captive animals, due to their living conditions, cannot control their situation, environment and activities, as they would in the wild (Tennessen, 1989). Even though animals are naturally exposed to predators, when they cannot influence the outcome of a situation, they are likely to be stressed by this situation. Lack of control is considered as the main stressors for captive animals (Zidar, 2009).

Resting was negatively correlated with time for the adults. This can be due to their preference to rest inside because of the decreasing temperature through the observation period and the weather getting less sunny, mainly rainy. In addition, studies demonstrated that over 3 months postpartum the time allocated to rest, by the mother, decreases (Gebauer, 2022; Liu et al., 2003; Osterrieder & Davis, 2011). Perhaps the need to lactate decreases over the time and being a very costly behaviour in mammals, less energy is allocated to this behaviour (Dechanupong, 2019; Starck & Ricklefs, 1998). Also, the data showed that over the weeks Laya and Wanju were significantly more frequently *Very close* and less frequently *Far*, suggesting that the mother was more careful when her cub was out. Furthermore, *Alert* was the mother's third most frequently observed behaviour but negatively correlated with time. Besides, the frequency of Laya and Shifu being *Very close* significantly increased over the time, as well as the number of *Aggression* for the male. *Aggression* was mainly observed between the male and his offspring and at the end of the data collection. This last finding is in line with Zidar's (2009) study stating that aggressive behaviour does not happen often in captive red panda but occurred from males towards cubs (among other situations).

In accordance with the literature, the peak hours of the studied red pandas corresponded to the feeding routine imposed by humans, and I noticed that it shifted when the mealtime was delayed. In fact, when the "red panda experience" occurred, morning mealtime was delayed of two hours and so the peak hour too. In a certain way, this mealtime shifting was perceived as enriching by the animals. Prior to the mealtime, I observed that some behaviours increased in frequency (*Moving* +14%, *Alert* +3%, *Exploratory* +2%, *Food foraging* +2%, and *Aggression* +1%) or new were performed (*Playing* 12%) compared to normal days without "red panda experience". Furthermore, the individuals were 31% less *Out of sight* on days with the "red panda experience". This suggests that changing mealtimes every other day or introducing irregular mealtimes may increase the frequency of occurrence of natural behaviours, and therefore improve the animal's welfare. Environmental enrichment also improves breeding, and rearing success and increases the chances of successful reintroduction into the wild (Swaisgood et al., 2001). In addition, in the middle of the data collection period, bamboo and berry plants were planted in the outdoor enclosures, giving a novel opportunity to Wanju, the mother, to show to her cub how to use these novel food sources. In fact, I observed Laya learning how to eat bamboo from those plants.

My study provides new insights into the social distances of red pandas. As red pandas are solitary, it is not surprising that across all individuals they were mostly *Far* from each other and due to the maternity the second most frequent distance was *Touching*. In fact, *Far* was the most frequent distance between the adults, and cub and father; and the second most frequent one between mother and cub. Mother and cub were principally *Touching*.

Research about the impact of visitors on the behaviour of captive red pandas is needed. In the presence of visitors, the activity rate of the red pandas was significantly higher. The "red panda experience" occurred during the same week as the zoo was open to the public. Therefore, this finding can either be an unintended positive effect of the "red panda experience", being perceived as enriching by the red pandas, so having an enrichment-like role; or be related to the general presence of visitors. In addition, the morning peak hour of activity in the presence of public, shifted to an hour later, likely due to the "red panda experience" again as half of the mealtime was 2 hours later. Perhaps, these findings should be taken with a grain of salt because they might not be caused by the zoo opening but the implications of the "red panda experience", as well as the short period of time of data collection in the presence of visitors (9 days versus 41 days without public).

Finally, I investigated the possible effects of temperature on the activity budget of the red pandas. The mother's activity rate was positively correlated with temperature. This can be linked to motherhood as she was increasingly more active, over the time, to accomplish her mother role. Furthermore, the inter-individual distance *Very close* was negatively correlated with temperature for all animals. Here, too, this may be the consequence of the cub's growth as well as the mating period approaching, therefore more incidents of aggression were observed and Wanju teaching her offspring how to perform natural behaviours.

The present study has limitations and could be improved by studying more than one mated pair and its offspring. They were only observed during daytime in autumn from the outside of the enclosure. However, my study provides new perspectives of the social distance and behaviour during maternal care in captive red pandas, as well as of new types of enrichment ("red panda experience") and effects of visitors on the animal welfare. Future studies could use infrared cameras in the indoor areas, particularly in dens, and perhaps GPS tracking collars to further investigate social distance in red pandas during maternal care. Moreover, it would be interesting to examine the effects of regular enrichment use on maternal behaviour and the mother's stress related to the cub growth.

6. Societal & ethical considerations

One of the primary ethical considerations that arise in my study is the need to ensure that the project is conducted with the utmost respect for the animals involved, and that measures are put in place to ensure their welfare is not compromised. The present study complied with the *European Union Directive on the Protection of Animals Used for Scientific Purposes* (EU Directive 2010/63/EU), the *European Union Zoos Directive Good Practices Document* (EU Directive 2015/07/EU), and with current Swedish animal welfare laws. An extra ethical approval was not required as all interventions of the study are considered as environmental enrichment for the animals and are thus covered by current European Union and Swedish animal welfare laws and directives for animals kept in zoos. In addition, the animals were not forced in any way to do or not do anything that they would not voluntarily and spontaneously do, and any changes in the method was discussed with the red pandas' keepers and consented by the zoologist and the veterinarian of Borås Djurpark. Accordingly, I had no reason to believe that my study imposed any stress or impairment of welfare in the animals.

In terms of societal considerations, my research findings may have a significant impact on the management of captive red pandas and their welfare. As part of the global conservation efforts for this species, zoos are responsible and expected to offer the best conditions possible to fulfil the animal's welfare and well-being needs. My findings may help to consider new forms of enrichment and considerations to take into account when it comes to enclosure design and placement choice. Additionally, my study may also have implications for the husbandry of this species in a zoo setting, by investigating the distance during maternal care, which is lacking in the current literature. Moreover, my results suggest a possible positive impact of the presence of public on the red pandas' activity and distance.

In conclusion, my study on captive red pandas' social behaviour and distance during maternal care addressed ethical and societal considerations to ensure that the research was conducted in a responsible and ethical manner. By doing so, the research contributes to a better understanding of social behaviour in solitary species. In addition, it gives insights into new types of enrichments, as interactive experience with visitors, benefiting the species welfare in captivity, and thus their conservation, as well as raising awareness about red pandas which, in turn, may help to raise funds for their conservation; and globally raise awareness about threatened species.

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