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Time Budget and Activity Patterns During the Mating Period of Flat-headed Cat *Prionailurus planiceps* in Captivity

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ABSTRACT.– This study focused on the daily activity of flat-headed cats *Prionailurus planiceps*, which are currently recognized as endangered. Activity of one male and one female cat in captivity was observed from 8–15 June 2017 by using video cameras at the Department of Conservation and Animal Health Research, Songkhla Zoo, Songkla Province, Thailand. Observations were gathered on each individual by *ad libitum* sampling for 24 hours (daytime 06:00–18:00 and nighttime 18:00–06:00). The observed behaviors and time budget were recorded and used for constructing an ethogram. Finally, the daily activities were analyzed and compared between the male and female. The activity patterns of the cats could be classified into six categories: maintenance, feeding, rest, affiliation, aggression, and vigilance. The cats were commonly active at night and rested during the daytime. The male cat spent more time to rest during the day and was more active than the female at nighttime. Meanwhile, the female presented longer periods of affiliation behavior than the male during daytime and spent more time feeding than the male at night. In addition, the activity patterns of these flat-headed cats were similar to the natural activity of leopard cats *P. bengalensis* and other felids in the genera *Felis* and *Leopardus*.

KEYWORDS: behavior, ethogram, Felidae

INTRODUCTION

Ex-situ conservation is a technique used to protect sensitive wildlife species from dramatic declines in their wild populations, and it is done outside their natural habitat. In the zoo, a behavioral study is an evidence-based approach that is crucial for animal husbandry and population management. Comparative information between captive and wild populations helps us to understand the minimum requirements of the species and can be applied to guide re-introduction programs (Kasso and Balakrishnan, 2013).

The flat-headed cat is known as one of the rarest felids in the world. They are small cats weighing approximately 1.5–2 kg (Muul and Lim, 1970). The habitats of these cats include primary swamp forests, lakes, streams and riverine forests in the lowland (Wilting et al., 2010). This niche—associated with freshwater—is reflected in some morphological adaptations, such as small webbing between the toes, a flattened skull, and large canine teeth that enhance their ability to catch slippery prey including fish and amphibians (Muul and Lim, 1970). The reproductive ecology of flat-headed cat is totally unknown. Knowledge of their mating system is also lacking, although possibly the cats mate all year round (Dmoch, 1997; Santymire et al., 2011). Their gestation period is about 56 days (Muul and Lim, 1970).

Because of habitat loss, the wild population of this species has dramatically declined (Bezuijen, 2000), and they are classified as a globally endangered species (IUCN, 2023). Unfortunately, the biology, activity and behavior of these cats are poorly understood. In the past five decades, only a few studies have recorded the ecology of flat-headed cats (Muul and Lim, 1970; Nowell and Jackson, 1996; Rasmussen, 2014), while studies on their behavior are even rarer.

Herein, we present the first ethogram, daily activity pattern and time budget of captive flat-headed cats during their breeding period. The behavioral data were collected at Songkla Zoo, Thailand. This species-specific study can be used to improve *ex-situ* breeding programs and can be enhanced to protect this species from extinction.

MATERIALS AND METHODS

Captivity and management

This study was conducted at the Small Cat Research Unit of Songkla Zoo, Songkla Province, Thailand. The research unit is separated from the exhibit zone, and is free from visitor disturbance. Animal housing for these cats has a total area of 75 m^2 and is divided into a row of four enclosures (Fig. 1A).

Activities of male and female cats in captivity were observed from 8–15 June 2017. The exact mating period of the flat-headed cat is still unknown. Reproductive data from congeners *Prionailurus viverrinus* and *P. rubiginosus philipsi* suggest that the cats can reproduce throughout the year, given a suitable

FIGURE 1. The enclosure for flat-headed cat *P. planiceps* at the Small Cat Research Unit of Songkla Zoo, Thailand. **A.** animal housing **B.** environment inside the enclosure.

environment (Dmoch, 1997; Santymire et al., 2011). Thus, our team observes and records the courtship behavior of cats in captivity all year round, and we have found that the cats exhibit courtship behavior many times a year. However, only the observation period described in this study provided a complete record of the cats' courtship behavior.

Mating introductions were set up when the cats showed signs of courtship behavior, such as paying more attention to the other sex or trying to initiate contact. Three enclosures were used for mating introductions of two adult males and one adult female, which was in its estrous cycle. However, only one pair of cats (male and female) were ready for observation. The subjects for this study were captive-born at Songkla Zoo in 2009 from wild-born parents.

The enclosure used for observations was divided into two partitions. The cats usually remained in the first partition and had contact only with the zookeeper, who used the second partition of the enclosure.

The first partitions of each cat were separated by concrete walls and wire mesh fencing; the second partitions were connected and could be opened to allow free movement of the cats between enclosures.

According to the animal welfare protocol, the food was provided between 09:00 and 10:00 and was available all day long to monitor any irregularity that may occur in captivity. The food items were presented in a tray from the second partition. The diet consisted of a measured amount of chicken meat, short-bodied mackerel and whole prey of mouse. Additionally, living fish were available in a pool for behavioral enhancement.

The enclosures provided for the flat-headed cat were open-air exhibits with a combination of natural and artificial environment elements. The floors of these enclosures were covered with soil and leaf litter. Small plants and dry logs were spread randomly, and a wooden box and an artificial log were provided in one corner as shelter for the cats. Fresh and clean water was provided *ad libitum* in the pool, which occupied 1/5 of the enclosure area (Fig. 1B).

This study was approved by The Zoological Park Organization under The Royal Patronage of H.M. the King and the Sanctuary's animal care and research staff. Animal care and use protocol approval number U1-07249-2560 was granted to PD.

Data Collection

Because the behavioral displays are influenced by the environment in which the animals live, we made our observations through a CCTV camera to avoid bias from disturbing the cats. The observations were performed by one researcher with a focal animal sampling method (Rose and Riley, 2021). Behavioral displays were recorded during the day (06:00–18:00) and night (18:00–06:00). The behavior of each cat was recorded 24 h per day during the eight consecutive days that the cats performed courtship behavior, resulting in 192 h of total observation time. Twenty-nine of the behavioral displays were recognized and classified into six categories of inferred function to construct an ethogram, as follows: rest, maintenance, aggression, affiliation, feeding, and vigilance. Description of each behavioral display was modified from a Standardized Ethogram for the Felidae (Stanton et al., 2015) to best fit the target cats in this study (Table 1).

Behavioral displays were categorized as inactive (rest) or active (all other behaviors). Daily activity patterns of the cats were constructed by calculating the proportion of circuits of active activity. A time budget for each category was expressed as the percentage of

TABLE 1. An ethogram of flat-headed cats *P. planiceps* observed at Songkla Zoo, Thailand in June 2017 (definitions derived from Stanton et al., 2015).

Functional category	Behavioral display	Definition
Rest		
	Sit	Cat is in an upright position, with the hind legs flexed and resting on the ground, while the front legs are extended and straight.
	Lay down	Cat's body is on the ground in a horizontal position, including on its side, back, belly, or curled in a circular formation.
	Sunbathe	Cat lays or sleeps under sunlight.
Maintenance		
	Defecate	Cat releases feces on the ground while in a squatting position.
	Groom	Cat cleans itself by licking, scratching, biting or chewing the fur on its body. May also include the licking of a front paw and wiping it over one's head.
	Urinate	Cat releases urine on the ground while in a squatting position.
	Stretch	Cat extends its forelegs while curving its back inwards.
	Scratch	Cat scratches its body using the claws of its hind feet.
	Clawing	Cat drags front claws along an object or surface, likely leaving visual marks behind.
Aggression		
	Bare teeth	Cat opens its mouth slightly while pulling lips back to expose teeth.
	Cuff	Cat strikes another with forepaw and contact is made. Claws are usually extended.
	Pounce	Cat leaps on another one.
	Head-body rub	Cat rubs its head or body against an object inside the captivity.
Affiliation		
	Follow	One cat travels closely behind another cat.
	Nap bite	The male grips the back of the neck of a female with his mouth while mounting.
	Mount	A male cat attempts intromission by straddling over the female with front and hind feet. In "small" cats, this may be accompanied by a nape bite and/or treading movements of the hind feet.
	Play	Cat interacts with something in a "non-serious" manner (i.e. where there is no intention to harm).
	Allogroom	Cat licks the fur of another cat's head or body.
	Sniff nose	Two cats smell the nasal regions of each other and touch each other with their noses.
	Social head rub	Cat rubs its head or any part of body on another cat.
Feeding		
	Attack	Cat launches itself at prey with extended forelegs and attempts to engage in physical combat.
	Drink	Cat ingests water by lapping up with the tongue.
	Eat	Cat ingests food (or other edible substances) by means of chewing with the teeth and swallowing.
	Guard	Cat keeps food away from other cat; this may be accompanied by aggression.
Vigilance		
	Walk	Forward locomotion at a slow gait.
	Jump	Cat leaps from one point to another, either vertically or horizontally.
	Stand	Cat is in an upright position and immobile, with all four paws on the ground and legs extended, supporting the body.
	Watch	Cat observes a specific stimulus subject.
	Sniff	Cat smells by inhaling air through the nose.

time spent per day, then a mean activity time was calculated for each category from the eight days of data collection. However, the data for the percentage of time spent per day were not normally distributed, so we performed a Mann-Whitney U-test to compare time budgets of the male and female. The analysis was performed by SPSS 2.0 software ver. 25, and the significance level adopted was 5% ($p < 0.05$).

RESULTS

A total of 192 hours of focal observations were analyzed for the male and female flat-headed cats during their mating period. During some periods of the data recording, the cats hid themselves away from the field recorded by CCTV, either inside or outside the shelter. During the eight-day observation period, the cats were not visible to the observer for an average of 77 minutes per day for the male and 110 minutes per day for the female. These periods were categorized as out-of-sight, and the data were excluded from all analyses. Some behavioral displays are shown in Fig. 2.

Daily activity pattern of flat-headed cats

The daily activity of the male and female cats showed similar patterns representing bimodal peaks. However, the peak activity of the female occurred slightly later than that of the male (Fig. 3).

During the daytime, the cats spent most of the time resting; they started to be active in the late afternoon (from 16:00) and were continuously active during the nighttime, with a high proportion of vigilance behaveiors (Fig. 4E, F). The level of active behavior of the cats was high at night, gradually decreasing from 03:00

FIGURE 2. Some functional displays of flat-headed cat *P. planiceps* in captivity. **A.** Feeding. **B.** Rest. **C.** Aggression. **D.** Affiliation.

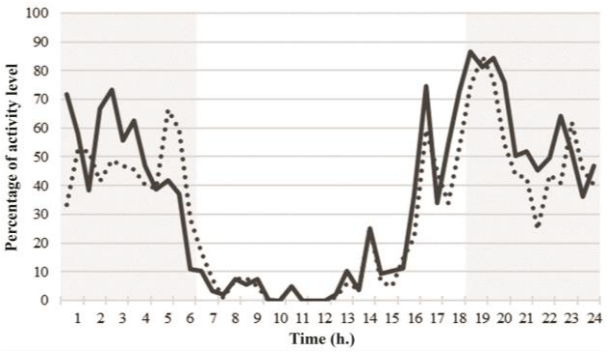

FIGURE 3. Pattern of active behavior of adult male (solid line) and adult female (dashed line) flat-headed cat *P. planiceps* in captivity at Songkla Zoo, Thailand.

onward. Active behaviors were observed less than 10% of the time from 07:00 to 15:00.

The maintenance category represents the cat essentially taking care of itself, providing comfort, and keeping healthy. This category is composed of six behaveiors: defecating, grooming, urinating, stretching, scratching and clawing. The cats started maintenance behaviors in the afternoon (15:00). The highest proportion of maintenance was exhibited by the male around 16:00 to 17:00, while the female exhibited a peak at 20:00 (Fig. 4B).

Signs of aggression include baring teeth, cuffing, pouncing and rubbing the head or body on objects inside the enclosure. Aggression categories occurred as a small proportion during the study period and were exhibited mostly by the female cat. The female usually showed aggression in protecting her food. The male, in contrast, tended to exhibit aggression when it was followed by the female over 30 minutes (Fig. 4C).

In this study, the affiliation category included any interactions between the cats related to mating such as social head rubbing, following, nap biting, mounting and allogrooming. These behaviors occurred during daytime and nighttime, and were more common for the female cat than the male (Fig. 4D). Both sexes showed a high proportion of interaction from late afternoon onward and throughout the night. Following display was exhibited by both sexes but was more frequent in the female cat. The female cat usually followed the male for a while, then trotted toward him and crouched

TABLE 2. Mean ± s.d. of the percentage of time spent on displayed behaviors by *P. planiceps* in captivity. Differences between means (*) were considered significant at $p < 0.05$.

Behavioral category	Day		Night	
	Male	Female	Male	Female
Rest	76.45±9.40	48.11±35.13	6.97±5.72	11.30±11.96
	p = 0.04*		p = 0.234	
Maintenance	2.42±2.11	0.83±0.82	3.36±1.21	4.11±2.28
	p = 0.07		p = 0.574	
Aggression	0.02±0.04	0.00	0.11±0.07	0.54±0.82
	p = 0.105		p = 0.574	
Affiliation	5.32±3.02	21.51±18.96	8.53±8.69	16.08±12.52
	p = 0.04*		p = 0.195	
Feeding	1.69±1.05	1.59±0.95	1.36±1.20	11.98±13.29
	p = 0.90		p = 0.04*	
Vigilance	14.07±7.27	27.93±30.54	79.66±10.64	55.24±23.06
	p = 0.505		p = 0.02*	

down in front of him to indicate that she was ready to mate. Mating habits occurred randomly 2–3 times per night during only 3 nights of the study period.

The feeding behaviors (including drinking) occurred mainly at night. The male cat actively consumed food from around 17:00. The feeding time of the female was longer and occurred several times overnight compared to the male cat (Fig. 4E). Interestingly, the cats usually removed food items from the tray and consumed them near the artificial pond.

Vigilance behaviors indicate that cats are alert to their environment. This category comprises five behaviors: walking, jumping, standing, watching, and sniffing. The vigilance behaviors of the male and female were exhibited in similar patterns. The cats started displaying vigilance behaviors at 16:00, with a peak in activity at 20:00 and again around 01:00 (Fig. 4F).

Activity time budget

During daytime, male and female cats spent the majority of time for rest, vigilance and affiliation categories. Comparison of activity time budgets between the male and female cats using the Mann-Whitney U-test showed a significant difference in the mean percentage of rest (Mann-Whitney, $U = 2.20$, $p = 0.04$), with the male cat taking more time to rest than the female. In addition, the percentage of time the female used for affiliation behaviors was significantly higher than for the male ($U = -2.38$, $p = 0.04$).

Affiliation and vigilance were the first and second most common activities at night, respectively, for both sexes, followed by resting in the male and feeding in the female. There also were significant differences between the male and female in percentage of time spent for feeding ($U = -2.24$, $p = 0.04$) and vigilance ($U = 2.70$, $p = 0.02$). The mean percentage of time spent is shown in Table 2, and the proportion of time spent in each category is shown in Figure 5.

DISCUSSION

This study has provided the first behavioral ethogram of flat-headed cats in captivity. Functional categories and behavioral displays are mostly based on the Standardized Ethogram for the Felidae (Stanton et al., 2015). However, some functional categories could not be recorded in this study, such as vocalization and exploration.

According to the observed daily activity, the cats were more active at night than in the day and exhibited peaks of activity at dusk and dawn, as in other crepuscular/nocturnal species. The activity of the flat-headed cats is congruent with other congeneric captive species, *Prionailurus bengalensis* (see Lynam et al., 2013), and other wild cat species *Panthera tigris* (Lynam et al., 2013; Mohd-Azlan and Sharma, 2006), *Neofelis nebulosa* (see Lynam et al., 2013), *Leopardus pardalis* (see Weller and Bennett, 2001) and *Leopardus tigrinus* (see Resende et al., 2014).

The cats used more time during the day for rest, and spent the night for active behavior. However, maintenance and affiliation behavior also occurred for short periods during this mating period. Unlike the Iriomote cat, *Prionailurus bengalensis iriomotensis*, the flat-headed cats spent more time on self-maintenance and interacting with other cats (Schmidt et al., 2009).

Although the percentage of time spent for maintenance behavior did not significantly differ by sex (Table 2), the male cat tended to spend more time for self-maintenance than the female. Interestingly, the maintenance behavior of the male usually occurred from late afternoon to early night, while the female exhibited affiliate behavior.

At night, the male was more mobile than the female, based on its higher proportion of vigilance (Fig. 4F). This activity pattern has been correlated with the home range size of wild cats, in that males have

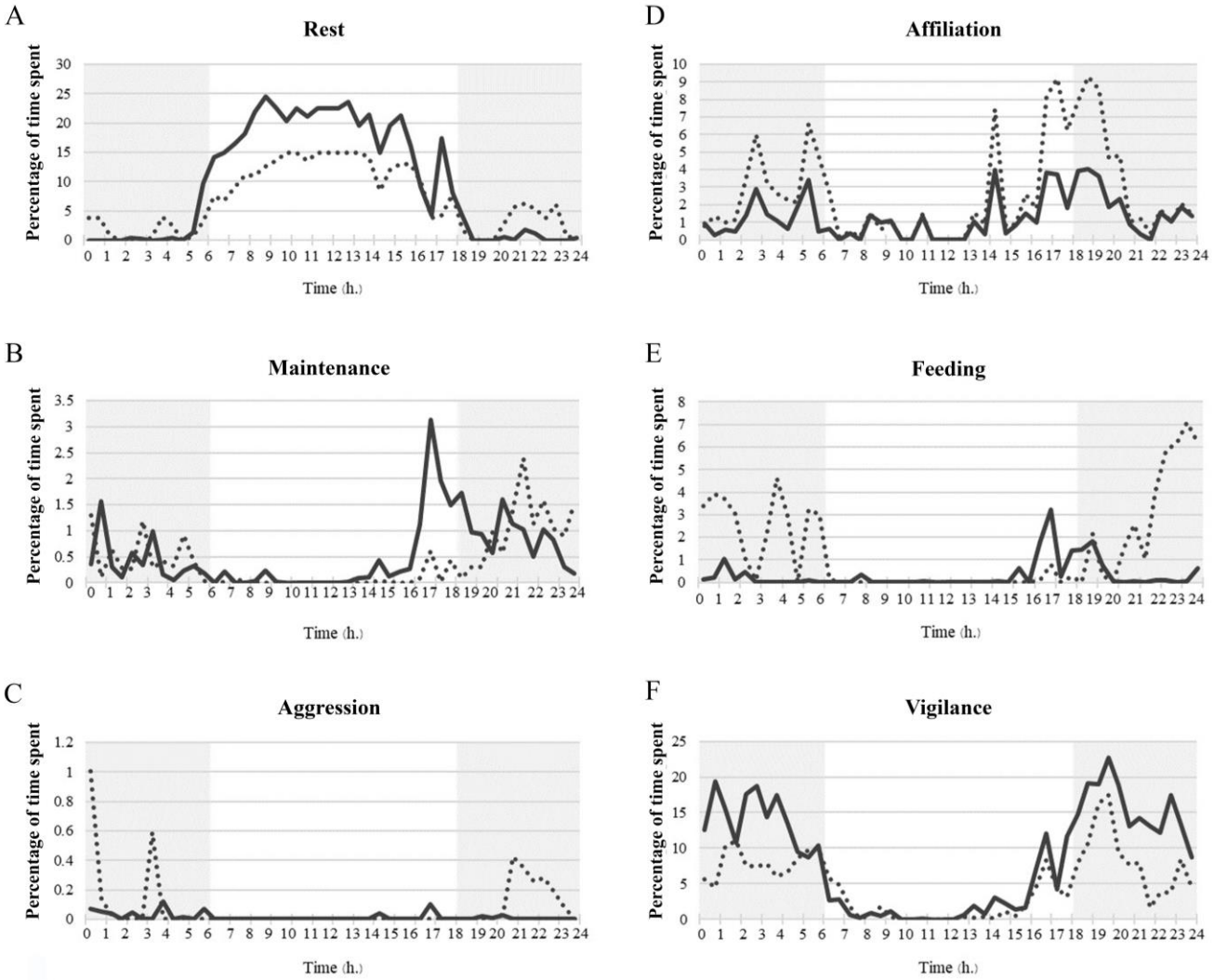

FIGURE 4. Patterns of activity for all six functional categories of behavior in an adult male (solid line) and an adult female (dashed line) flat-headed cat *P. planiceps*. **A.** Rest. **B.** Maintenance. **C.** Aggression. **D.** Affiliation. **E.** Feeding. **F.** Vigilance.

larger home ranges and are more active than females (Ferreras et al., 1997; Odden and Wegge, 2005; Mohd-Azlan and Sharma, 2006; Chen et al., 2016). This common pattern suggests that males have to allocate more time and energy to finding female mates, food, and defending their territory (Herbst and Mills, 2010).

The feeding of the cats also occurred at nighttime. The cats usually removed the food from where it had been presented and consumed it near the artificial pond inside the cage. This behavior corresponds to observations from wild populations, where the cats usually fed near water sources (Nowell and Jeckson, 1996; Bezuijen, 2000). Before eating a living mouse, the cats soak the prey in the water; likewise, this behavior has been displayed by a captive flat-headed cat in the Malaysian Zoo (Muul and Lim, 1970; Rasmussen, 2014). Interestingly, this behavior has not been found in congeners that also live near the water like *Prionailurus viverrinus*. In this study, food-guarding displays were found only for the female cat.

Courtship behavior of flat-headed cats mostly occurs during the night. The pattern was similar to domestic cats and other wild cats (Ewer, 1973), but slightly different in detail. In this study, the female cat tended to follow the male, while in domestic cats, males will follow the females.

Allogrooming, one of the affiliation behaviors, can be found in both wild and domestic cats during the mating period, including the captive flat-headed cats in this study. However, allogrooming displays in domestic cats also occur outside of the mating season (Beaver, 1980; Gittleman, 1987). Likewise, the proportion of aggressive behavior of captive flat-headed cats in this study was lower than would be expected during mating. Most of the aggression exhibited by the female cat was for protecting her food items, whereas the only

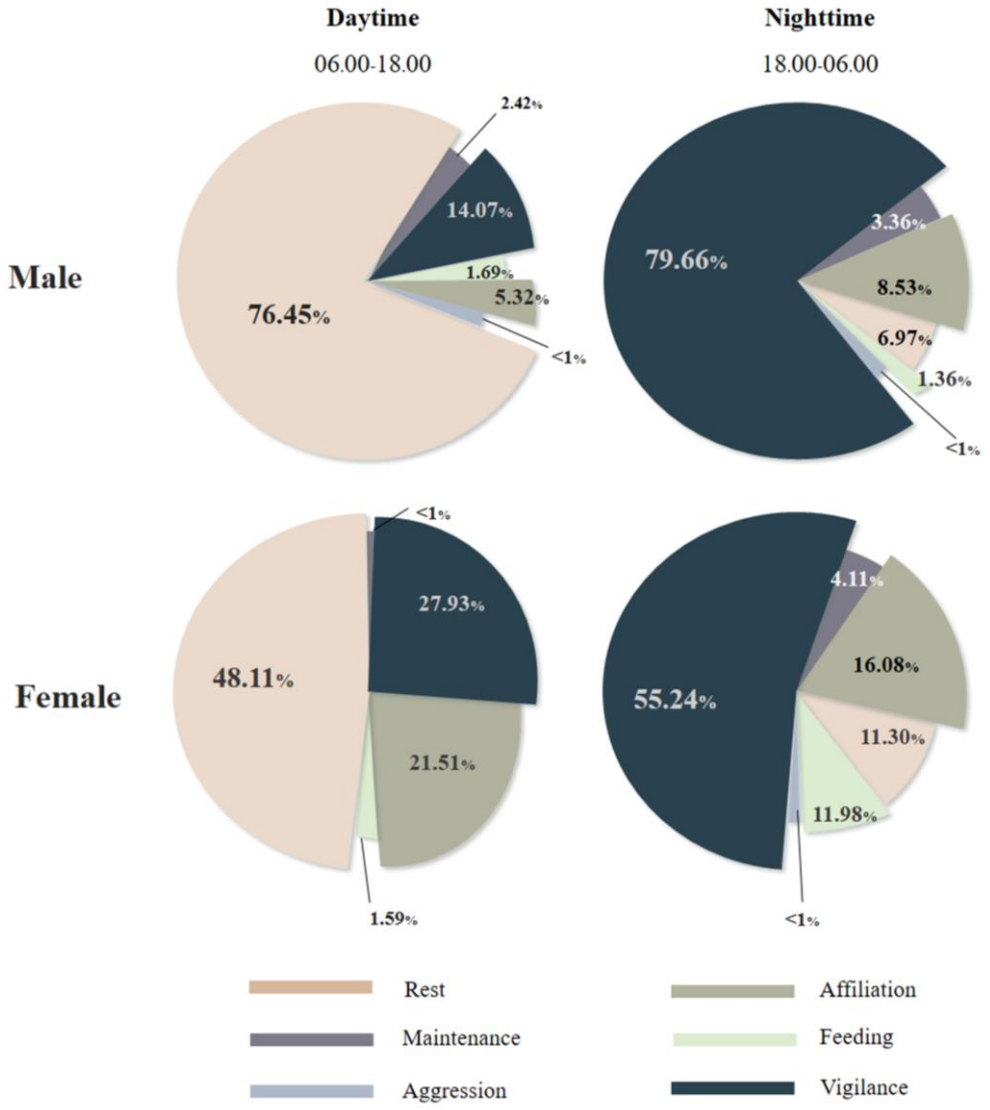

FIGURE 5. Time budgets of adult male and female flat-headed cats *P. planiceps* in captivity by functional category.

aggressive behavior displayed by the male was rubbing to mark his territory.

This study has provided novel information about the daily activity pattern of captive flat-headed cats, which may be valuable for captive breeding and reintroduction programs. However, the behavior was unobserved for 77–110 minutes per day, when the cats were out of view. Additional CCTV cameras should be installed inside the enclosure to avoid any blind spots for future study.

Little information is available about the behavior of flat-headed cats for comparison, either from natural habitats or captivity. Most information was derived from the few direct sightings and camera-trap records (Muul and Lim, 1970; Nowell and Jackson, 1996; Wilting et al., 2010; Wilting et al., 2016; Wadey et al., 2017). Moreover, captive cats are kept only at Taiping Zoo, Malaysia, and at Songkla Zoo, Thailand, for education (Sunquist and Sunquist, 2002). Unfortunately, all cats that are kept at Taiping Zoo are female. Although data from this study is based on a small sample size, it represents a foundation for gathering more information about this endangered species. Additionally, studies should be conducted to cover both breeding and non-breeding periods to provide more complete behavioral information.

CONCLUSION

This study has provided novel information about the behavioral displays of flat-headed cats. Overall, our results indicate that the behavioral patterns of flat-

headed cats observed in captivity are congruent with those recorded in wild individuals of the congeneric species *Prionailurus bengalensis* and other wild cat genera *Felis* and *Leopardus*. Given the limited knowledge of the behavior and husbandry of rare species, examining their daily activity provides significant biological knowledge, particularly data on courtship behavior, which is essential for management plans. Information about the behavioral stereotype of a species and the minimum requirements of an animal increases the success rate of captive breeding. This can benefit population recovery in captivity and can be modified for pre-release training as well.

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