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Articles

Parental behavior of Lynx lynx and Puma concolor: insights from offspring rearing in captivity?

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Animal behavior can serve as an important indicator of welfare for zoo inhabitants. The maternal behaviors exhibited by lynx and puma in captivity are crucial not only for the survival and well-being of their cubs but also provide valuable insights for species conservation programs. We analyzed the motor activity of a male and female Siberian lynx and a male and female puma during the period when they were raising their kittens, which had not yet left the shelter at the time of observation. Our ethological monitoring revealed both similarities and differences in behavior across species and sexes. We found that males of both species exhibited passive behaviors more frequently than females. Overall motor activity was higher during the evening observation periods. Notably, the male lynx spent significantly less time in the shelter compared to the other studied animals, likely due to his close cohabitation with the female and their kittens. In contrast, the male puma was kept nearby but separately from the female and her offspring. Abnormal behaviors were observed in nearly all animals, except for the female lynx. The female puma exhibited the highest level of abnormal activity, frequently carrying her kitten in her mouth for extended periods, which suggests a high level of stress. The intraspecific Shorygin indices of behavioral similarity between male and female lynxes and pumas were relatively low, at 42% and 45%, respectively. In comparison, our previous research indicated that the behavioral similarity index between male and female Eurasian lynxes without offspring was 87%. This suggests that the presence of kittens significantly increases the differences in time budgets between males and females.

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Keywords

Behavior, kittens, *Lynx lynx*, abnormal activity, *Puma concolor*, well-being, zoo

Introduction

One of the primary goals of keeping animals in zoos is to preserve the gene pool of endangered species. To achieve successful captive breeding, zoos must adhere to the principle of the five freedoms (Veselova and Blokhin 2023). Physiological assessments, such as measuring cortisol levels, are used to monitor the well-being of these animals (Heimbürge et al. 2019; Radical et al. 2023). However, there is a pressing need to develop and refine methods for identifying conditions that may cause discomfort to the animals. Since discomfort is highly species-specific and can even vary among individuals, it is challenging to evaluate using standard measures (Solodovnikova et al. 2019). One accessible marker of animal distress that does not require costly equipment is the observation of abnormal behavior (Babb 2020).

In the wild, maternal care is vital for the survival and development of cubs, typically involving behaviors such as den selection, nursing, grooming, and teaching hunting skills. While studies on wild pumas provide baseline knowledge, understanding maternal behavior in captivity is crucial for effective management, welfare assessment, and breeding success.

Captivity fundamentally alters the maternal capacities of both lynx and puma, with numerous studies highlighting the role of stress in diminishing the quality of maternal care. Animals in captive environments may experience heightened anxiety due to human presence, limited space, and inadequate environmental enrichment. For instance, research indicates that lynx mothers in high-stress situations exhibit decreased nursing frequency and increased distance from their cubs, leading to significant developmental challenges for their offspring (Fanson, 2009). Pumas also exhibit a range of behavioral changes under captivity. Factors such as high noise levels, frequent human interactions, and limited environmental complexity can result in abnormal maternal behaviors, including neglect or excessive aggression towards cubs. Managing these stressors is critical, as maternal care patterns significantly influence cub survival rates and overall well-being. Captive puma mothers display essential maternal behaviors vital for cub survival, including nursing, grooming, and protective actions.

While captivity offers certain advantages, such as safety and reduced competition for resources, it can also lead to deviations in natural maternal behaviors. The stress associated with captivity can impair a mother’s ability to care for her young. For example, Lagos et al. (2017) found that female pumas in high-stress environments, characterized by frequent human interactions and noise, exhibited increased aggression and less effective nurturing behaviors compared to those in more secluded, naturalistic conditions. Additionally, captive conditions can adversely affect cub development. Early separation from the mother for health assessments or educational programs can lead to behavioral issues in young pumas. Laundre (2009) reported that cubs raised with constant maternal interaction demonstrated better social behaviors and adaptability when introduced to larger enclosures.

Maternal behavior in captive pumas reflects a complex interplay between natural instincts and the effects of the captivity environment. By providing enrichment and fostering conditions that support the expression of natural maternal behaviors, wildlife facilities can enhance the well-being of pumas and contribute to their conservation. Further research is needed to explore the long-term impacts of captivity on maternal behavior and cub development, yielding insights that can improve management practices and aid in the successful reintroduction of pumas into the wild.

The effects of captivity on maternal behavior in lynx are also multifaceted. Stressors such as human presence and noisy environments can detrimentally affect maternal care. Studies have shown that

lynx mothers subjected to frequent human observation experience heightened anxiety, leading to decreased nursing frequency and altered grooming behaviors (Kachamakova and Zlatanova 2014). Additionally, improper enclosure design, which fails to meet the behavioral needs of lynx, can lead to abnormal behaviors and potentially compromise maternal care. It is essential to create environments that minimize stress and discomfort, thereby promoting normal maternal behaviors. Enclosures that offer adequate privacy and enrichment opportunities support the expression of natural maternal instincts and cub development.

Breeding feline species is a priority for many zoos worldwide (Bulaeva 2016). Our study focused on a pair of Siberian lynxes (*Lynx lynx wrangeli* Ognev, 1928) and a pair of pumas (*Puma concolor* Linnaeus, 1771), both of which had kittens that had yet to leave the shelter. Pregnancy, childbirth, and subsequent care of offspring introduce additional stress (Alekseeva et al. 2020). Therefore, it is crucial to monitor stress levels and abnormal behaviors promptly, particularly in females, as the survival of the offspring largely depends on the mother’s well-being.

Materials and methods

The study involved two pairs (one male and one female) of Felidae family members at the Barnaul Zoo "Forest Fairy Tale," both pairs having cubs and all born in captivity.

Siberian lynx. The female was born in 2012, and the male was born in 2017. At the time observations began, they had two kittens that were 17 days old. The male lynx cohabited with the female and the kittens in the same shelter. Lynxes exhibit minimal sexual dimorphism, with males and females averaging the same weight (Naidenko 2005). This lack of pronounced differences may contribute to the relatively peaceful interactions between partners during social contact in the breeding season. According to Erofeeva and Naidenko (2020), Eurasian lynxes display a high percentage of friendly and sexual behaviors toward males (>75% of all social interactions), making it feasible for a male and female to live together with their offspring.

Puma. The female was born in 2012, while the male was born in 2011. By the start of observations, they had three kittens that were 14 days old. The male and female pumas were housed separately but were positioned within sight of each other.

The main enclosure for the lynxes measures approximately 200 m^2 and includes two additional enclosures of about 30 m^2 each, connected by a safe corridor. The wooden shelter within this area is roughly 10 m^2 and is equipped with stumps, a wooden table, and logs. In contrast, the pumas have two enclosures each measuring about 100 m^2, which include a large section with a feeding table, logs, and suspended wheels, and a smaller 10 m^2 section containing wooden shelters. All enclosures are around 3 meters high and feature a sandy floor covered with natural vegetation. The animals are fed twice daily, and cleaning occurs each morning.

The observations were conducted using the continuous recording method (Popov and Ilchenko 1998). This method allows for the comprehensive and continuous documentation of all animal behaviors, which facilitates the identification of behavioral sequences, assessment of temporal characteristics, and establishment of functional relationships among different behaviors. Observations were carried out for one hour in the morning (7:30-8:30 AM) and one hour in the afternoon (3:30-4:30 PM) for three consecutive days for each pair of animals. The observed behaviors were categorized into four forms of motor activity (Blokhin et al. 2017):

1. Inactive Behavior: No motor activity; includes lying down and sitting without moving (see Fureix, Meagher 2015).

2. Normal Behavior: Encompasses locomotion, manipulation, hunting, exploration, feeding, and social interactions.

3. Abnormal Behavior: Includes behaviors such as females carrying kittens in their mouths and pacing. Pacing is defined as repetitive locomotion along a fixed pattern (e.g., back and forth) without a clear goal or function. It must be performed at least twice consecutively to be classified as stereotypic (Stanton et al. 2015).

4. Shelter Behavior: The amount of time spent out of sight of the observer.

To assess the similarity of behavioral patterns between the two animals, we calculated the Schorygin similarity coefficient (Zheltenkova et al. 2000):

$SHR = \sum \min (p_i1, p_i2)$

This coefficient is determined by the sum of the minimum values (p_i1, p_i2, etc.), representing the frequency of various behavioral forms exhibited by each animal. The values of the coefficient range from 0, indicating no similarity, to 100%, indicating complete similarity. The collected data were statistically analyzed using MS EXCEL and JAMOVI (2022, version 2.3), with the Mann–Whitney U test applied for nonparametric samples.

Results

At the time of observation, both pairs of animals were raising their offspring, which had not yet left the shelter (Tables 1 and 2).

Activity	Male	Female	Male	Female
12.06.2023	7.45-8.45 (AM)		3.45-4.45 (PM)	
Inactivity	92	0	50	17
Normal behavior	8	0	25	47
Abnormal behavior	0	0	25	0
Shelter behavior	0	100	0	36
13.06.2023	7.40-8.40 (AM)		3.30-4.30 (PM)	
Inactivity	45	0	8	0
Normal behavior	3	0	8	18
Abnormal behavior	0	0	39	0
Shelter behavior	52	100	45	82
14.06.2023	7.40-8.40 (AM)		3.40-4.40 (PM)	
Inactivity	63	0	12	0
Normal behavior	3	0	10	20
Abnormal behavior	0	0	58	0
Shelter behavior	62	100	20	80

Table 1. *Time budget of Siberian lynx (data presented as a percentage of total observation time)*

Activity	Male	Female	Male	Female
15.06.2023	7.35-8.35 (AM)		3.40-4.40 (PM)	
Inactivity	0	0	34	0
Normal behavior	0	0	48	27
Abnormal behavior	0	0	18	73
Shelter behavior	100	100	0	0
16.06.2023	7.40-8.40 (AM)		3.45-4.45 (PM)	
Inactivity	0	0	42	0
Normal behavior	0	0	25	20
Abnormal behavior	0	0	25	80
Shelter behavior	100	100	8	0
17.06.2023	7.45-8.45 (AM)		3.45-4.45 (PM)	
Inactivity	0	0	47	0

Abnormal behavior	0	0	20	57
Shelter behavior	100	100	0	26

Table 2. *Time budget of puma (data presented as a percentage of total observation time)*

During the morning observations, the female lynx remained in the shelter with her kittens 100% of the time. In contrast, the male lynx spent significantly less time in the shelter, ranging from 0% to 52% of his total time budget (Fig. 1). In the evening, the female stayed in the shelter for 36% to 82% of the time, while the male stayed for only 0% to 45%. On average, the male lynx spent significantly less time in the shelter than the female ($T = 2$, $P \leq 0.008$, Fig. 2).

The female lynx allocated most of her time to natural activities outside the shelter, demonstrating a small proportion of inactive behavior on just one observation day. In contrast, the male preferred passive behaviors such as lying down or sitting ($T = 2$, $P \leq 0.01$). While the male's natural activity levels were higher in the evening than in the morning, they remained lower on average compared to those of the female ($T = 2$, $P \leq 0.04$, Fig. 2).

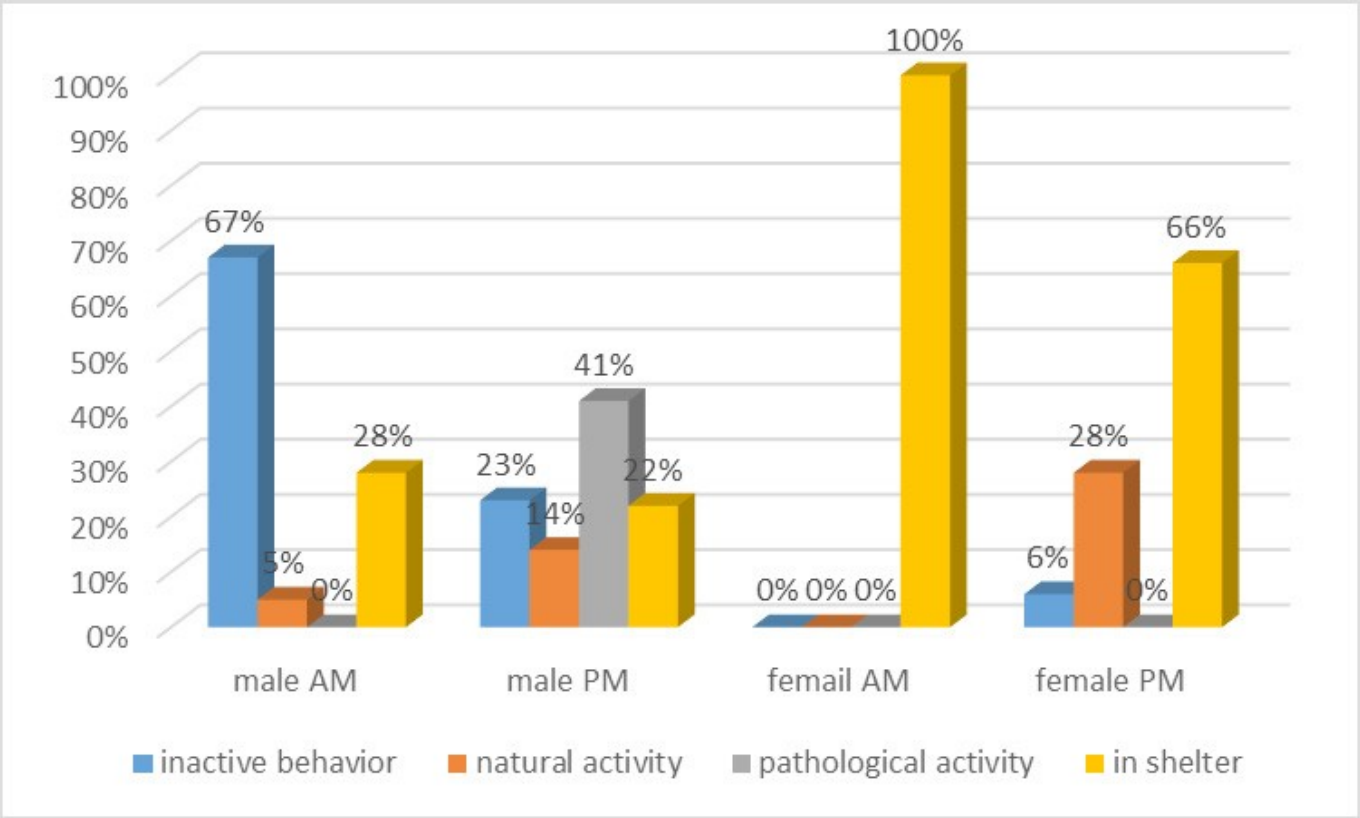

Figure 1. *Behavioral activity of male and female lynx during morning (AM) and evening (PM) periods.*

Another significant difference between the male and female lynx was their level of pathological activity. Throughout the observation period, the female lynx did not exhibit any abnormal behaviors, while the male displayed a notable amount of pacing, ranging from 25% to 58% of the time on different observation days. Additionally, this abnormal activity in the male lynx was only observed during the evening hours ($T = 0$, $p < 0.032$, Fig. 2).

We calculated the Schorygin coefficient only for the evening observation periods because the female spent the entire morning in the shelter (Table 3).

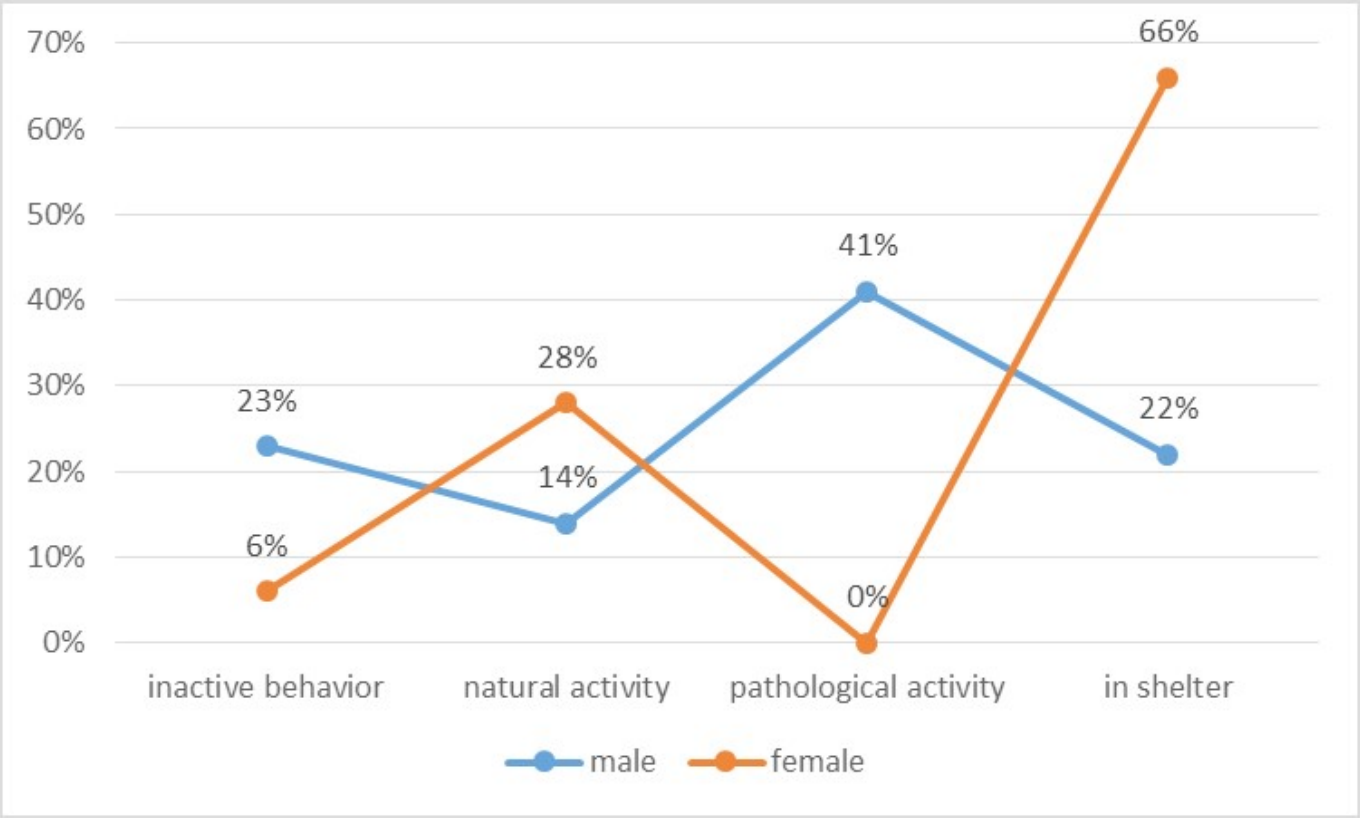

Figure 2. *Evening behavioral activity of male and female lynx.*

Activity	Activity share from total budget (%)		Minimal value (%)
	Male lynx	Female lynx	
Inactivity	23	6	6
Normal behaviour	14	28	14
Abnormal behaviour	41	0	0
Shelter behavior	22	66	22
Total	100	100	42

Table 3. *Schorygin similarity coefficient for a pair of lynxes*

During the morning observation hours, both male and female pumas remained in the shelter at all times, similar to the female lynx. The male pumas exhibited significantly higher levels of inactive behavior compared to the females. In the evening, the natural activity of male pumas was slightly higher than that of females, averaging 25% for males and 21% for females; however, this difference was not statistically significant.

Both sexes displayed abnormal activity in the evening. According to the study by Morales et al. (2017), pumas without kittens also exhibited such behavior during the evening hours, specifically between 16:00 and 18:00. In our investigation, the female puma demonstrated a significantly higher level of abnormal activity, averaging 70%, compared to just 21% for the male ($T = 0$, $P < 0.05$, Fig. 4).

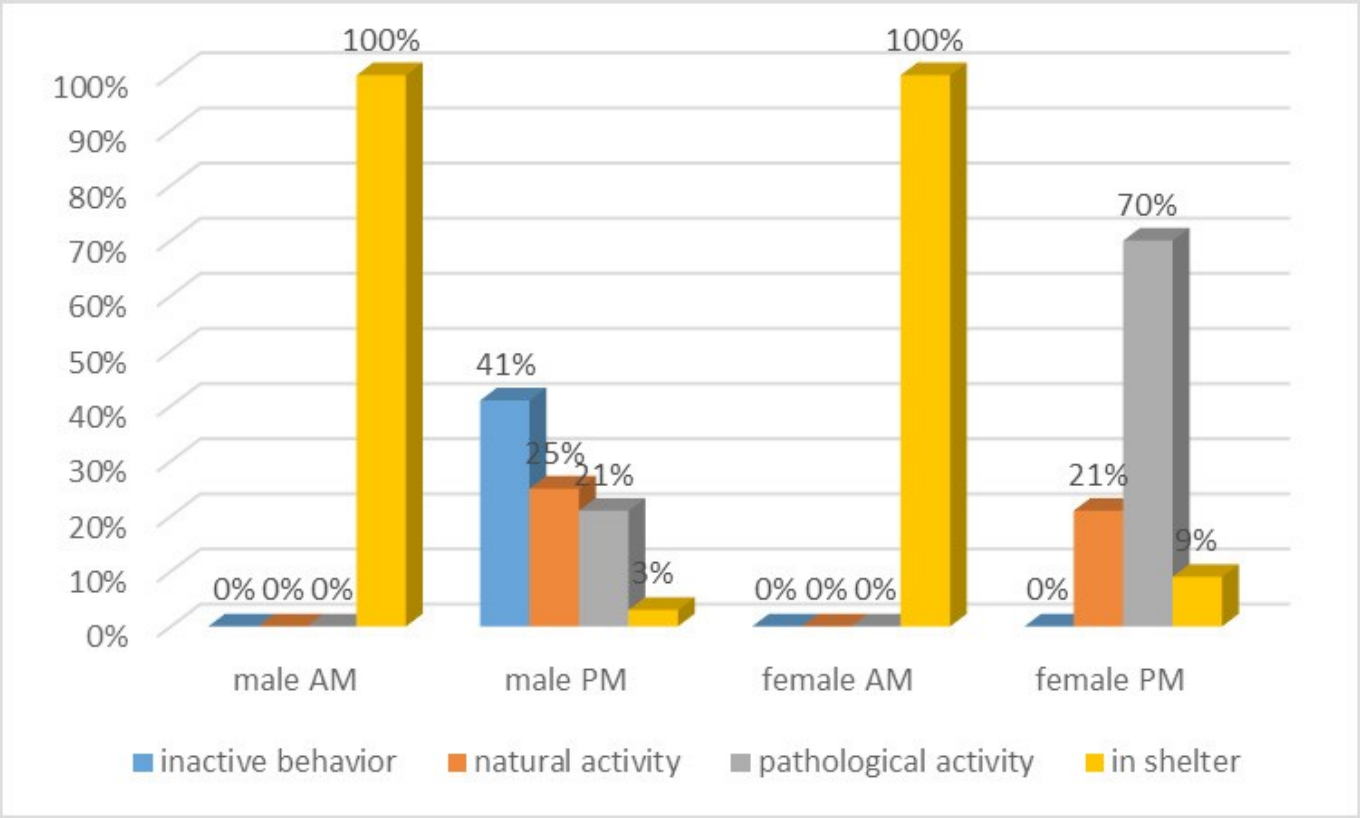

Figure 3. *Behavioral activity of male and female puma during morning (AM) and evening (PM) periods.*

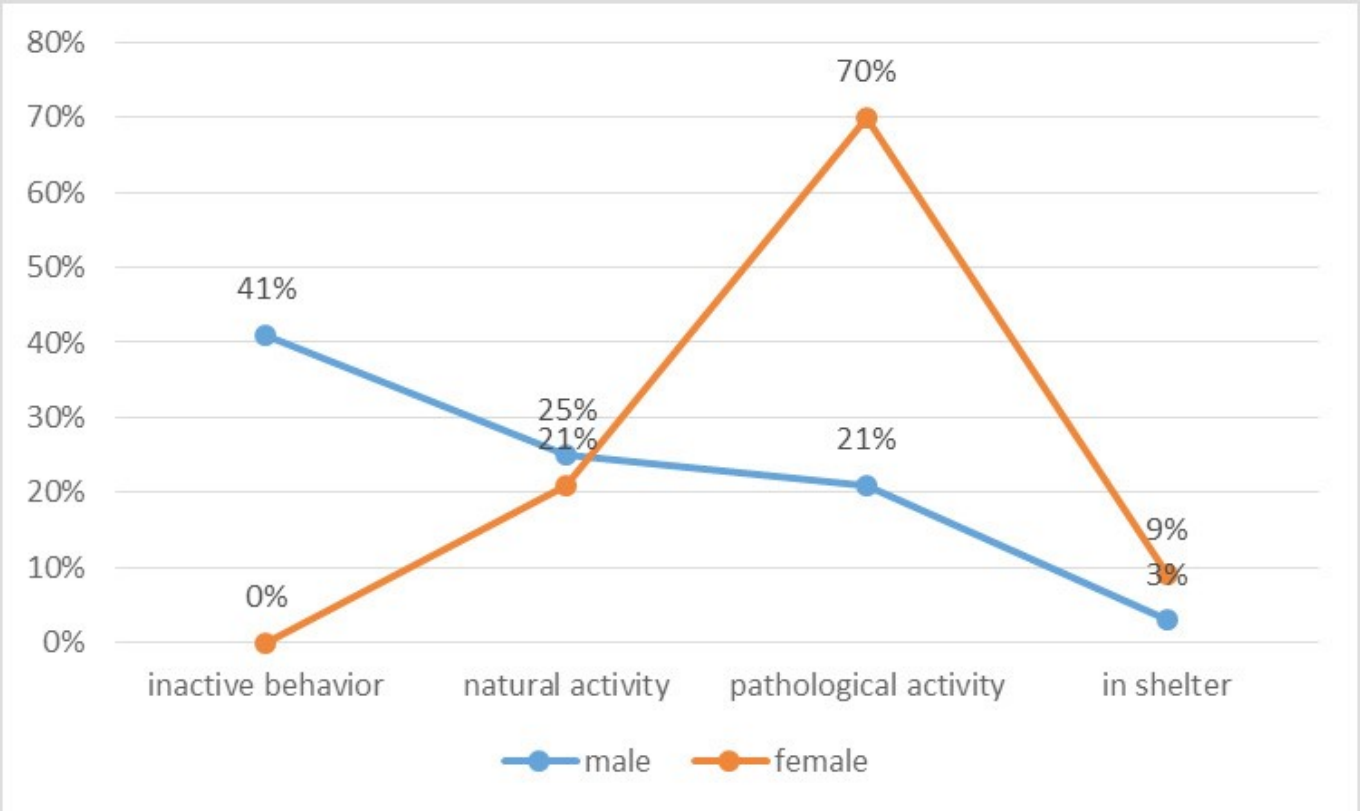

Figure 4. *Evening behavioral activity of male and female puma.*

There are similarities in the manifestation of inactive behavior between lynxes and pumas. In both

species, females outside the shelter either do not demonstrate this type of behavior at all (puma) or show it very briefly (6% of the time budget in the female lynx, Fig. 5).

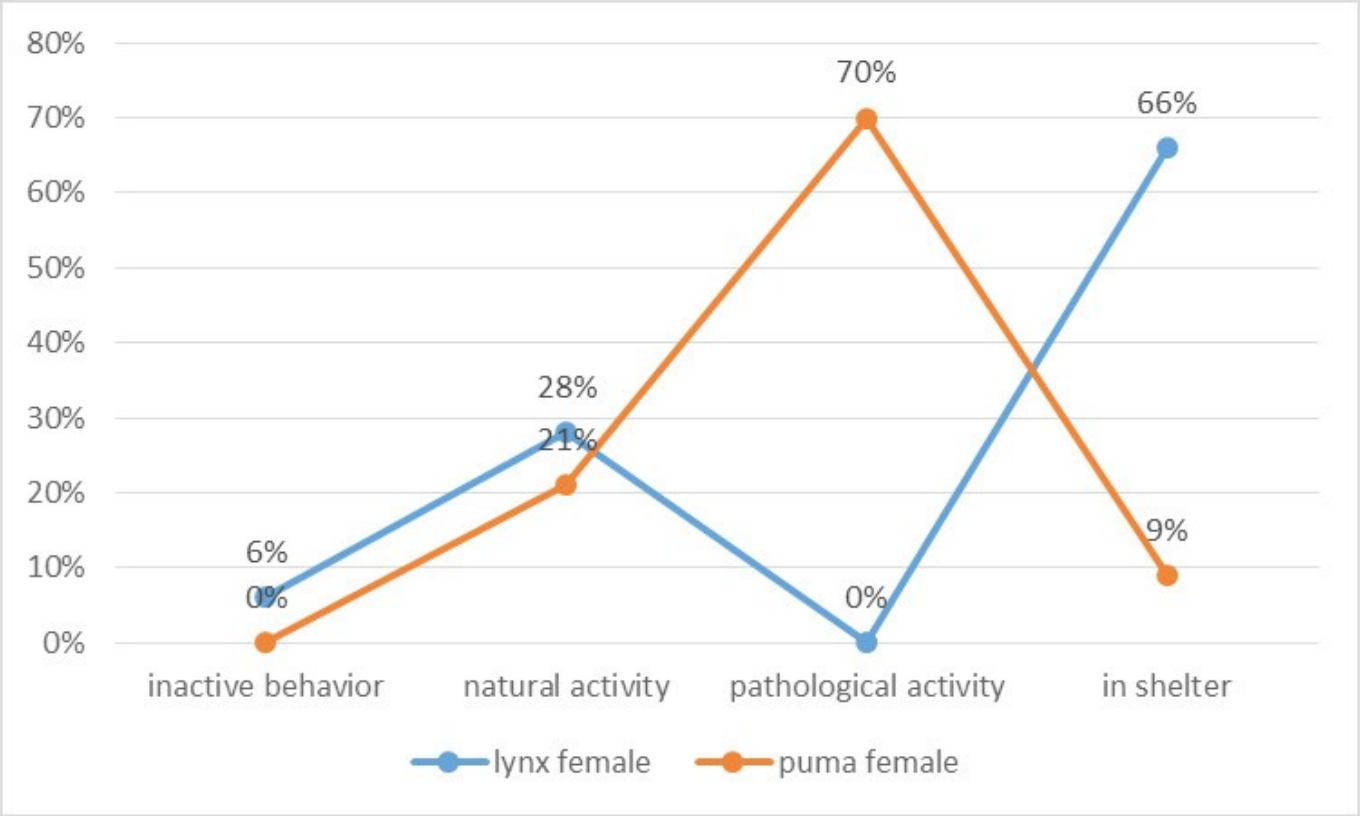

Figure 5. *Behavioral activity of female lynx and puma.*

In males of both species, the proportion of inactive behavior outside the shelter during the evening hours averaged between 23% and 41% over the three-day observation period. This level of inactivity was significantly different from that observed in females ($T = 2$, $P < 0.005$, Fig. 6).

For pumas, the Schorygin coefficient calculated during the evening observation hours was 45%, which is comparable to the coefficient for lynxes, which was 42% (Table 4).

	Male lynx	Female lynx	Male puma	Female puma
Male lynx	–	42	61	64
Female lynx	42	–	34	30
Male puma	61	34	–	45
Female puma	64	30	45	–

Table 4. *Schorygin coefficient matrix (%) for all studied animals (evening observation hours)*

The Shorygin coefficient between the male lynx and the male puma was 61%, while the coefficient between the females was only 30%. Notably, the index between the male lynx and the female puma was the highest in our study at 64% (Fig. 7).

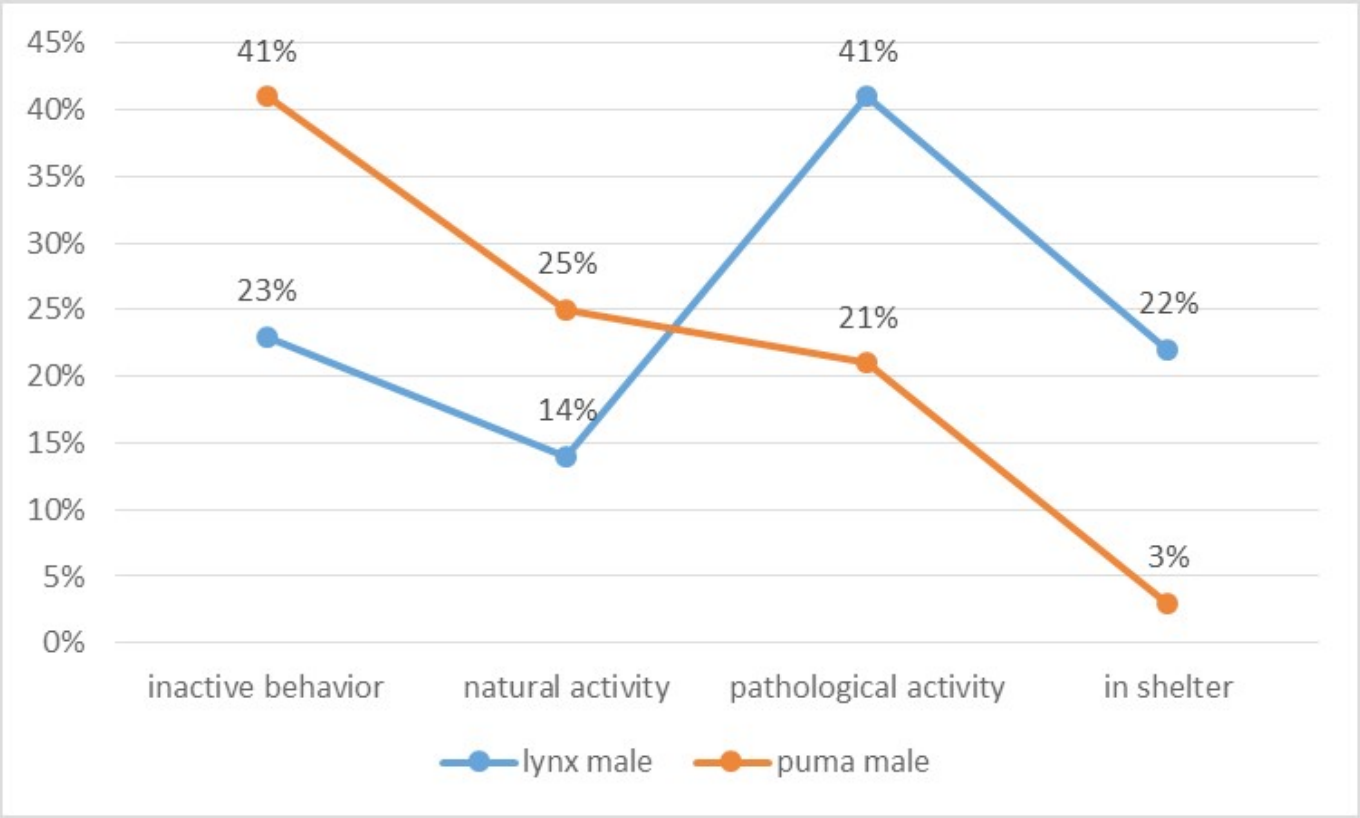

Figure 6. *Evening behavioral activity of male lynx and puma.*

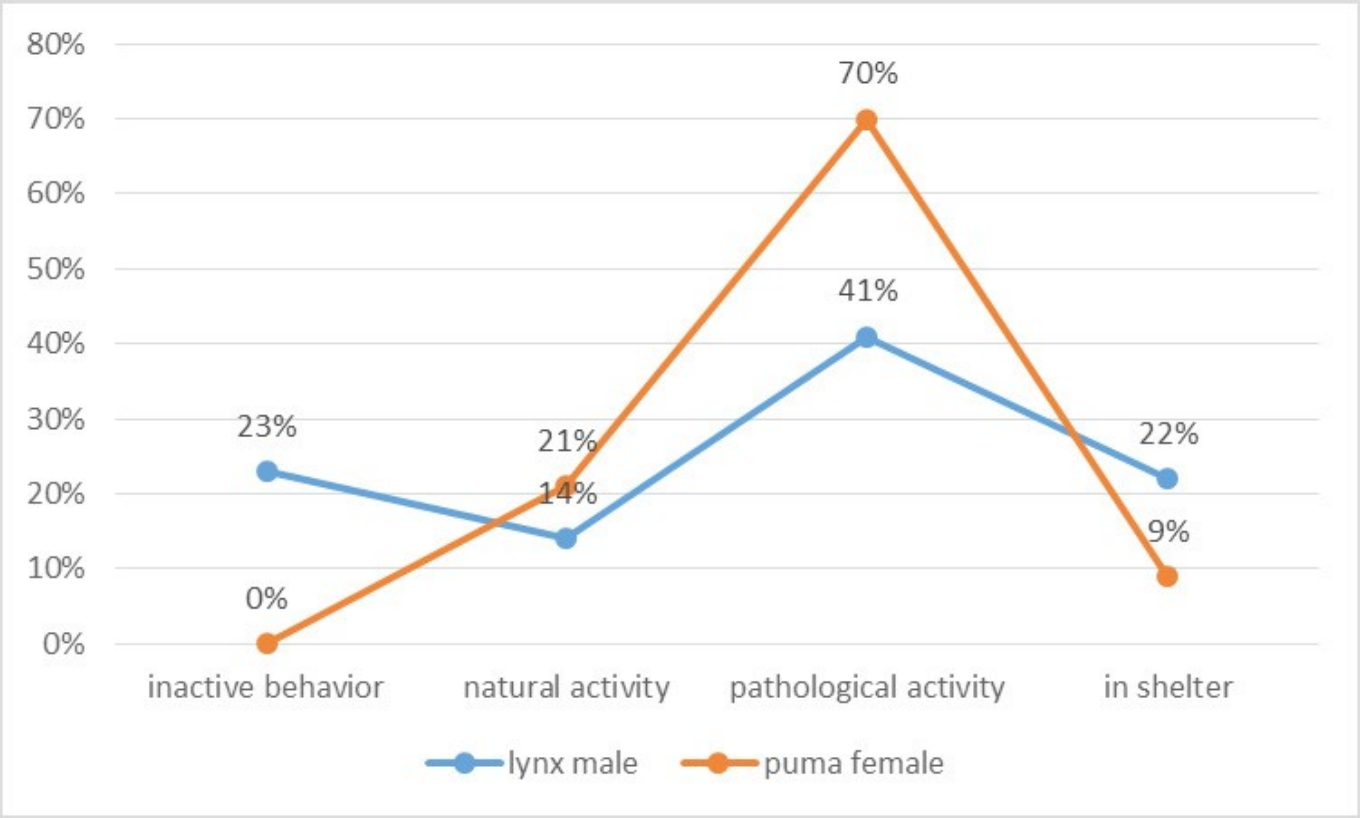

Figure 7. *Evening behavioral activity of male lynx and female puma.*

Discussion

Understanding the maternal behaviors exhibited by these solitary feline species provides insights into their reproductive strategies, juvenile development, and survival rates. According to Boutros et al. (2007), the choice of den site can significantly influence kitten survival, with well-concealed locations offering greater protection from potential threats. Maternal behavior in lynxes is not static; it can be influenced by various factors including environmental conditions, prey availability, and the presence of potential threats (Fernandes et al. 2002). Furthermore, maternal behavior can also be affected by stressors such as human encroachment or habitat fragmentation, which can lead to increased vigilance or defensive behaviors.

The maternal behavior exhibited by lynxes is a multifaceted aspect of their biology, encompassing nesting, feeding, protective, and teaching behaviors. These actions have significant implications for the survival and development of the young and are influenced by environmental and social factors (Schmidt 1998). Future research could provide deeper insights into the impact of changing ecosystems on maternal strategies and juvenile outcomes in lynxes, thereby contributing to more effective conservation and management efforts for these solitary felines. Understanding these dynamics is vital, especially in the context of habitat loss and humaninduced changes in their environment (Engebretsen et al. 2024).

When comparing the behavior of all studied animals, the male lynx exhibited notably distinct patterns during the morning hours. Unlike the other animals, he spent the majority of his time outside the shelter. The presence of small kittens likely accounts for the female lynx's decision to remain in the shelter throughout the morning. In contrast, the male puma also did not leave the shelter during this time. This difference in behavior may stem from the varying housing conditions of the two species. The male puma was kept in a separate enclosure from the female and her offspring, thus having his own shelter, whereas the male lynx shared his shelter with the female and the kittens.

Current literature does not provide clear data on the male lynx's role in raising and protecting offspring in the wild. Some evidence suggests that male lynxes deliberately leave prey near the den while protecting their territory from potential threats, such as wolves (Sidorovich 2022). Since we did not observe any aggressive interactions between the male and female lynx during our study, it is plausible that the male's longer duration outside the shelter serves a territorial protective function. We also compared the male lynx's activity patterns between morning and evening observations. In the morning, he exhibited a high level of inactivity (lying or sitting), while during the evening hours, there was a significant reduction in his inactive behavior, coupled with an increase in motor activity. This pattern aligns with previous findings that non-reproductive animals also show increased activity during evening hours (Korkina and Borisenko 2019; Wegele and Veselova 2022; Yerga et al. 2015). The observed increase in activity might reflect a circadian rhythm, as many feline species are known to be more active during the evening and night (Tumlison 1987). Furthermore, pacing (considered a abnormal activity) was noted only during the evening. This increase in various environmental stimuli – such as feeding procedures and a higher number of zoo visitors – could contribute to reactive anxiety, which may, in turn, lead to an uptick in both natural and abnormal activities in the male lynx. Veselova and Palkina (2023) also noted that the degree of abnormal behavior is influenced by visitor numbers at the zoo. Additionally, the female lynx's presence outside the shelter in the evening could have impacted the male's behavior.

Among the observed animals, the female lynx uniquely displayed any form of abnormal activity during the observation period. While she was outside the shelter, she engaged in natural behaviors, including feeding, toileting, and active movements around the enclosure. Given that the female spent most of the day in the shelter with her kittens, it is likely that when outside, she favored more active forms of behavior over passive ones. The activity levels of male and female pumas also differed. Similar to the lynx, the male puma exhibited a higher level of inactivity. Both the lynx and

puma males spent relatively little time outside their shelters, primarily because their kittens had not yet left the nest. During this time, the female pumas demonstrated a high level of motor activity while outside.

The female puma displayed the highest level of abnormal activity, particularly with behaviors such as carrying a kitten in her mouth for extended periods, indicative of significant stress. Such abnormal behaviors can result in harm or even fatality for the cubs (Savelyeva and Lovchinovskaya 2019). The reasons behind this behavior could stem from various factors, including the individual psychophysiological characteristics of the female and random stressful events that might have affected her. Another potential influence on her anxiety and subsequent abnormal behaviors could be the proximity to other large predators, such as lions. Previous studies indicate that such conditions can heighten the concentration of glucocorticoid metabolites in animal waste (Veselova, 2017). The impact of being near other feline enclosures on behavior has also been demonstrated in the case of the Far Eastern leopard (Antonenko et al. 2016). Furthermore, the presence of the male puma near the offspring's shelter could trigger abnormal behaviors. In many felid species, social interactions, especially during the mating season, tend to be limited. *Puma concolor*, showing significant sexual dimorphism in size (Gay and Best 1995), may also experience increased aggression from females towards males, particularly in species with pronounced size differences (Erofeeva and Naidenko 2020).

Our study results reveal a trend in the behavior of male lynxes regarding their time spent in the first two activity categories. As shown in Fig. 8, there is a similarity in behavioral trends between the females as well. Time spent in the shelter shows comparable patterns among males. These observations may indicate similar patterns of male behavior between these feline species during the period of rearing their offspring. The Shorygin coefficient further supports this similarity; the index value for the males was 61%, while the index between males and females of the same species ranged from 42% to 45% (Table 3). In contrast, the index between the females was only 30%, primarily due to significant differences in abnormal activity (Figure 7). Thus, our study suggests that male behavior shows greater similarity in the distribution of time budget compared to females among these felid species. Notably, the highest Shorygin coefficient – 64% – was observed between the male lynx and the female puma, attributed to their higher levels of abnormal behaviors. Previous research indicated that, outside the breeding season, abnormal activities in females are generally less prevalent than in males (Babb 2020). In our observations, however, both the minimum and maximum percentages of abnormal behavior were recorded in females. As noted earlier, the intraspecific Shorygin coefficients between males and females in lynxes and pumas were relatively low (42% and 45%, respectively). Our past data (Antonenko et al. 2019) indicated that the behavioral activity similarity coefficient between male and female Eurasian lynxes without off-spring was 87%. The presence of kittens appears to significantly increase the differences in time budgets between males and females.

Understanding the distinct maternal behaviors of lynx and puma in captivity underscores the need for tailored management practices that cater to the specific needs of each species. Creating environments that mirror natural habitats, including hiding spots, varied terrains, and minimal human disturbance, is essential for promoting natural maternal instincts.

Wildlife facilities must prioritize staff education on the behavioral ecology of both species to optimize population management strategies. Regular behavioral assessments and stress-relief initiatives, including enrichment programs designed to mimic natural flora and prey interactions, have shown promise in enhancing the quality of maternal care. By fostering environments conducive to natural maternal behavior, we can improve the success rates of breeding programs and ultimately enhance conservation efforts for these iconic species.

Conclusions

The time budget of felines with kittens reveals both differences and similarities in their behavioral activities. In the morning, three out of the four observed animals, excluding the male lynx, remained inside their shelters. When outside, inactive behavior was more common among the males of both species. Notably, both male lynxes exhibited abnormal behavior, specifically pacing, which was only observed during the evening hours. The female puma displayed a particularly high level of abnormal activity by carrying a kitten, indicating significant stress.

To alleviate this stress, it is essential to minimize auditory and visual disturbances near the female puma's enclosure. This could involve relocating her shelter to a more secluded area, adjusting the proximity to other animal species, and reducing visitor impact.

The examination of maternal behaviors in lynx and puma in captivity reveals significant differences linked to their ecological adaptations and highlights the profound impact of captivity on these behaviors. Continued research is vital for advancing our understanding of species-specific maternal care patterns and fostering effective management practices that optimize the psychological and physical well-being of both mothers and cubs. As we strive to balance conservation goals with animal welfare, informed approaches will be instrumental in preserving lynx and puma populations for future generations.

It is important to note that this study was conducted on a limited number of animals, so the results cannot be generalized to all representatives of these species in zoos. However, the findings can enhance the care and breeding conditions for Felidae in this specific instance and serve as a benchmark for further research in this area.

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