MEDDOCS Open Access Publisher

ISSN: 2640-1223

Journal of Veterinary Medicine and Animal Sciences

Open Access | Research Article

An investigation into the Behavior, Sociality and Enclosure Use of Group-Housed Lions and Tigers

Elena Giulia Galardi[1ǂ]; Martina Fabbroni[1ǂ]; Fabio A Rausa[2]; Richard Preziosi[4]; James Edward Brereton[3]; Giovanni Quintavalle Pastorino[1]*

[1]Faculty of Life Sciences, The University of Manchester, Oxford Road, Manchester, UK.

[2]Zoo Safari of Fasano, Fasano (BR), Italy.

[3]University Centre Sparsholt, Westley Lane, Sparsholt, Winchester, Hampshire, UK.

[4]Manchester Metropolitan University, All Saints Building, All Saints, Manchester, England.

***Corresponding Author(s): Giovanni Quintavalle Pastorino**

Faculty of Life Sciences, The University of Manchester, Oxford Road, Manchester, UK.

Email: g_pastorino@hotmail.com

ǂEqual contribution: Martina Fabbronia and Elena Galardi contributed equally to this work.

Received: Apr 06, 2021

Accepted: May 12, 2021

Published Online: May 14, 2021

Journal: Journal of Veterinary Medicine and Animal Sciences

Publisher: MedDocs Publishers LLC

Online edition: http://meddocsonline.org/

Keywords: *Panthera leo*; *Panthera tigris*; Felid; Social interaction; Social network; Affiliative behavior; keeper; Paw treading.

Abstract

It is common practice in zoological collections to house lions (*Panthera leo)* in prides, yet other felid species are typically housed in pairs or singly. This study investigated the effects of group-housing on a pride of 21 lions, and 10 tigers (*Panthera tigris)* at the Fasano Zoo, Italy. Both species were housed in large, safari-style exhibits, allowing animals to either interact with or avoid conspecifics. For both species, measures included behavioral sampling, sociality and assessment of enclosure use. The study revealed that lions spend comparatively more time engaged in social behavior, whereas tigers spent more time engaged in locomotion and maintenance activities such as grooming. There was no difference in aggression levels between the two species. Social network maps identified that tigers tended to divide into small, social units, associating with one or two preferred individuals and generally avoiding others. Lions on the other hand appeared to associate in species-typical prides. With the size of the enclosure and the number of individuals, the group appeared to separate into two well-differentiated prides. Enclosure zone use supported these findings across both species, showing that for tigers, enclosure zones tended to be used by only a few individuals. By contrast, there were shared enclosure zones which were frequented by members of the two prides, yet relatively little crossover in space use between the two groups. The study suggests that for well-established socially-housed tiger groups, aggression may not always be elevated and group-housing might be tolerated under certain circumstances, though more research would be beneficial before conclusions are drawn.

Cite this article: Galardi EG, Pastorino GQ, Fabbroni M, Rausa FA, Preziosi R, et al. An investigation into the Behavior, Sociality and Enclosure Use of Group-Housed Lions and Tigers. J Vet Med Animal Sci. 2021; 4(1): 1068.

Introduction

Zoos and aquaria play a key role in the conservation of wild animals through their engagement with captive breeding, research and education [1,2]. For example, zoos can provide opportunities for the public to meet animals they may not be able to experience elsewhere, allowing them to develop appreciation for endangered species and the role of conservation [1]. These collections may be essential for conservation breeding, as a potential source of animals for future reintroduction attempts [3].

One particular taxonomic group in need of conservation breeding is the Felidae Family [4]. This Family shows some diversity of animal sizes, from the sand cat (*Felis margarita)*, to the tiger (*Panthera tigris)* [5]. The obligate carnivore diet of most felids makes them particularly susceptible to extinction, as any threats impacting prey populations will also indirectly impact the felids [5]. As a general rule, felids are rare in the wild, as large populations of prey species are required in order to maintain a sustainable food source for predators [5]. Given their direct and indirect threats and their competition with humans over farmed animals and natural resource, felids are an excellent taxonomic group for zoos to select for conservation breeding purposes.

Large captive populations are essential if captive animal genetic diversity is to be maintained long-term [6]. However, the animal carrying capacity of the world's zoos is not indefinite. The number of zoos which are able to house felids safely is limited, and this impacts the population sizes in captivity. For example, the Critically Endangered snow leopard (*Panthera uncia)* captive population was recorded at 541 individuals in 1992 [7], yet a 2020 survey using the global Zoological Information Management System (ZIMS) database revealed only 410 individuals in captivity [8], despite the fact that the species is recorded to breed well in captivity [9]. This reduction in population size is likely a result of contraception, to prevent more offspring being produced than can be housed. Dedication of more exhibits to the keeping of snow leopards is likely to have a detrimental effect on the zoo carrying capacity of other felid species which have similar husbandry requirements.

Enclosure availability appears to be a limiting factor in terms of felid captive conservation, so some consideration should be paid to the social grouping of big cats. In the wild, the lion (*Panthera leo*) is described as a social species, forming prides of related individuals [10,11], whereas many other species are described as solitary [5]. However, the sociality of felids may not be quite so clear-cut: in the wild, social interactions between related leopards have been documented [12], and cheetahs (*Acinonyx jubatus)* are known to form coalitions [13,14]. Given the difficulties associated with observing wild felids, it is possible that some species have the capacity to be more social than the literature suggests.

Felid social grouping

Lion wild prides are normally composed of 1–21 adult females with offspring and a temporary coalition of 1–9 adult males [4,5]. The pride is a "Fission-Fusion" society and members are seldom found together, except for mothers that have pooled their offspring into a "Crèche" [6].

Lions are the only felid species with a matrilineal social system. The same combination of selective pressure and ecological opportunity (their habitat shows a high density of big herbivorous, easier to hunt in group) that led the lions to follow the group life does not exist in other felids [5].

On the other hand, tigers are solitary except when with dependent cubs. Although it's not common to observe close associations between females, due to their territoriality and aggressive nature [5] there is evidence of temporary assemblages of tigers with no aggressions at unusually large kill sites, where the tiger that made the kill always ate first [5].

From an historical perspective, captive felids have often been maintained in male-female pairs, possibly in an attempt to enhance breeding success [5]. Despite the fact that this is not a natural social grouping, many species have been shown to cohabit well and even breed successfully in male-female pairs [5]. However, pairings are not always conducive to good breeding, as shown in the historically poor breeding of zoo-housed cheetahs [14]. Additionally, the territory size of wild felids appears to be dependent on food availability: in environments where food is plentiful, territory sizes may be smaller and animals may become more tolerant of conspecifics [15].

Some of this behavioral plasticity in terms of territory size and sociality may influence how felids act in captivity. Researchers have identified that felids that are far ranging in the wild are more likely to stereotype in captivity [16], and that feeding frequency and exhibit size can impact the prevalence of pacing behavior [17,18]. The measurement of stereotypy is a commonly used method of assessing animal welfare in captivity [16], and while it should not be used as the sole indicator, it is valuable for identifying possible welfare issues.

Given that exhibit space is at a premium, it is important to assess the behavior of captive felids to determine their welfare state. As previously mentioned, felids are commonly housed in pairs [5], but there are exceptions of three or more individuals in the same enclosure [5,10] so there is a need for research to investigate any potential welfare impacts of this style of keeping.

Materials and methods

Study Subjects and Location

The aim of the study was to investigate the behavior of socially-housed lions and tigers. The study was conducted at the Fasano Zoo Safari in Italy, and investigated a pride of 21 lions and a streak of 10 tigers (Table 1&2). Prior to data collection, the project was ethically approved by the University of Milan and the Fasano Zoo Safari. All animals could be individually identified for observations.

Table 1: IDs and genders of lions, with the number of sessions and duration in minutes of observations per animal.

ID	Sex	Number of sessions and minutes of observation per animal
L1	F	25 (125 min)
L2	M	27 (135 min)
L3	F	26 (130 min)
L4	F	28 (140 min)
L5	F	28 (140 min)
L6	M	29 (145 min)
L7	M	27 (135 min)
L8	M	28 (140 min)
L9	M	29 (145 min)
L10	M	29 (145 min)
L11	M	26 (130 min)
L12	M	29 (145 min)
L13	M	27 (135 min)
L14	M	29 (145 min)
L15	M	27 (135 min)
L16	F	26 (130 min)
L17	F	27 (135 min)
L18	F	26 (130 min)
L19	F	26 (130 min)
L20	F	12 (60 min)
L21	F	10 (50 min)

Table 2: IDs numbers and genders of tigers in study.

ID	Sex	Number of sessions and minutes of observation per animal
T1	M	30 (150 min)
T2	F	29 (145 min)
T3	F	27 (135 min)
T4	F	30 (150 min)
T5	F	29 (145 min)
T6	F	30 (150 min)
T7	F	30 (150 min)
T8	M	30 (150 min)
T9	M	30 (150 min)
T10	M	30 (150 min)

Data collection was conducted during the summer season, from July 2019 until August 2019. This is considered peak season, so the average amount of visitors was high and not changed during the period of observation, so it was not considered as an influencing variable. Visitors could enter the enclosure between 09:00 and 16:00.

Behavioral data Collection

The felids were video-recorded by two observers using a continuous focal sampling method [18] with a Sony Handycam HDR CX240E and a Canon Legria HF R806, for five-minute observation periods per subject, three times per day. On some occasions, animals were out of sight and therefore could not be recorded: see Tables 1 and 2. The observations were collected from observers' personal vehicle using the entire available enclosure to optimize the data collection of the focal subject's behaviors, without interacting or disturbing the animals and always in a safe condition. Animals were selected for observations using a random number generator to choose the individual, until all individuals had been observed once for the observation period.

An ethogram was then developed using a previously published standardized ethogram for Felidae [19], which was subsequently adapted for use specifically for *Panthera* species [20,21]. The ethogram consisted of more than 100 behaviors, later condensed into 14 general categories (Table 3).

Table 3: General categories of behaviors observed for lions and tigers.

Name	Description
Affiliative behavior	The felid interacts with another individual in a non-aggressive way (e.g. touching noses, allogrooming, laying close together).
Agonistic behavior	The felid interacts with another individual in a non-affiliative way (e.g. biting, baring teeth, slapping).
Comfort	The felid engages tranquil behaviors that may indicate that is comfortable and relaxed (e.g. rolling, paw treading[a]).
Enrichment interaction	The felid interacts with an enrichment item (e.g. biting, playing)
Exploratory behavior	The felid engages with its environment (e.g. approaching, licking sniffing objects).
Inactive	The felid is at rest and stationary or performing minimal movements (e.g. laying, sitting, standing alone).
Locomotion	The felid moves around its enclosure (e.g. walking, running).
Maintenance	The felid engages in behaviors that maintain its own hygiene (e.g. self-grooming, urinating, bathing, defecation).
Marking	The felid engages communicative behaviors that result in a physical change to the environment (e.g. scratching, spraying).
Reproductive behavior	The felid interacts with another individual with a view to breeding (e.g. ano-genital sniffing, the Flehmen response, nape biting, mounting, lordosis).
Solitary play	The felid engages with its environmental objects other than enrichment, and may scratch, chase, or paw objects.
Stereotypic	The felid engages movements that seem to have no apparent goal or function (pacing).
Other	The felid engages behaviors that are not included in the others categories.
Out of sight	The felid is not visible.

Paw treading[a]: Was a new behavior, and was described as: The felid stays on back or lateral and shakes one, or two or four paws up and down simultaneously. This behavior was observed in carnivores such as domestic cats (see Youtube videos https://www.youtube.com/watch?v=HnyjEV13R60 https://www.youtube.com/watch?v=mx9B2Tw3C3g&t=6s). But also in a video of a snow leopard from the Big Cat Sanctuary, in UK (https://www.instagram.com/p/CASPGjhAbEn/).

Behavioral data was recorded using the Behavioral Observation Research Interactive Software (BORIS) v. 7.9.6. BORIS is an open-source event-logging software for video/audio coding and live observations. In addition, in this study were also insert modifiers, that identify to who or what the subject is directing a behavior, as a function of BORIS that permit to link the subject that made the action to the receiver. In some case the modifiers where interpreted as different adjectives to explain better the behaviors.

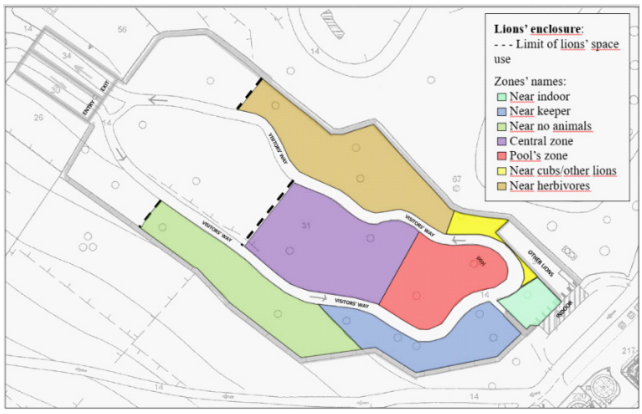

Figure 1: Lion enclosure zones.

Table 4: Names and descriptions of zones for lions and tigers.

Lions		Tigers	
Name	**Code on the map**	**Name**	**Code on the map**
Near indoor zone	A	Near entry	A
Near keeper zone	B	Near panoramic	B
Near no animals zone	C	Near cub zone	C
Central zone	D	Brother zone	D
Pool zone	E	Big pool zone	E
Near cubs/other lions zone	F	Near indoor/juvenile zone	F
Near herbivores zone	G	Near exit zone	G
		Near Asiatic black bear zone	H

Data analysis

After recording was completed using the BORIS software, data were uploaded to Excel™ 2016, where activity budgets were developed and descriptive stats were recorded. Data were then uploaded to Minitab version 19 for statistical analysis. The raw amount of data collected per lions' group was not consistent as a result of out of sight observations: Analysis was therefore conducted on the behavior and zone use values which had been transformed into percentages.

Then the activity budgets were generated with a time budget function of BORIS and the amount of time spent out of sight was used as a correction factor, so that all animals were measured only on the time they were visible to the observers.

Enclosure use

In addition to behavior, the enclosure use of animals was recorded using a continuous focal sampling method for five minute observation periods [18]. Both exhibits were partitioned into different zones based on the biological function of each area and its proximity to the public and other animal species (Figure 1, 2, Table 4).

For each observation, several extraneous variables were recorded in order to determine their effect on felid behavior and enclosure use. The variables were the weather and temperature, which were standardized by making use of an iPhone app, a count of the number of visitors that walked past the exhibit, and the date and time.

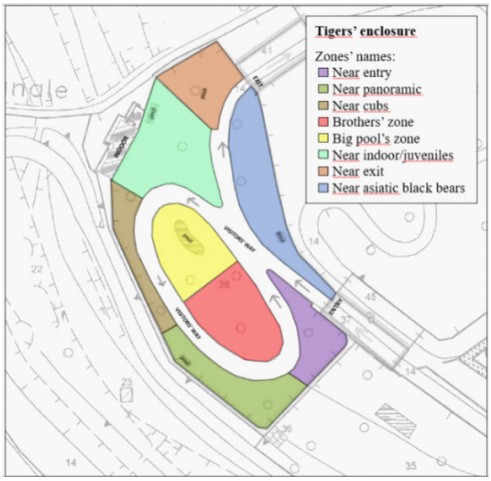

Figure 2: Tiger enclosure zones.

To test whether there was a significant difference in behaviors between lions and tigers, individual behaviors were tested for normal distribution. All behaviors resulted not normally distributed: Mann Whitney U tests were therefore used to compare all behaviors.

Social proximity information was converted into an association index that was prepared using UCInet and then uploaded to Netdraw [22,23] to develop social network maps.

Results

Comparison of behavior

A comparative activity budget for lions and tigers was generated (Figure 3). Exploratory and inactive behavior occurred at similar proportions for both groups, whereas considerable behavioral differences were identified for others. Comparative Mann Whitney U tests were run for all behaviors (Table 5), revealing that scent marking, affiliative and reproductive behavior occurred more frequently in lions, and locomotion, maintenance and solitary play was observed more often in tigers.

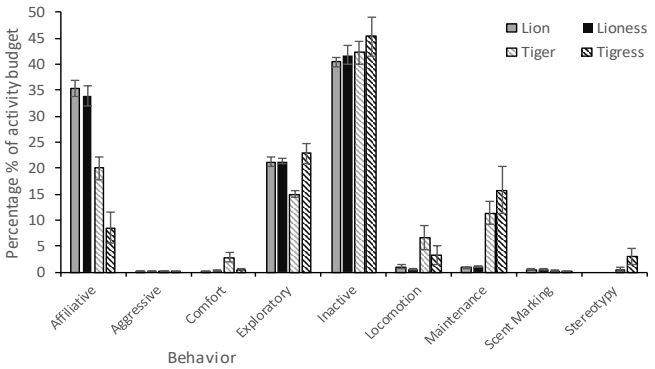

Figure 3: Comparative lion and tiger activity budget (+/- standard error), with out of sight observations removed.

Table 5: Comparison of lion and tiger behavior, using Mann Whitney U tests.

Behavior	U	P
Affiliative behavior	438	< 0.001
Aggressive behavior	339	0.916
Avoidance	291	0.051
Comfort	300	0.111
Enrichment interaction	NA	NA
Exploratory	358	0.364
Inactive	303	0.17
Keeper request	302	0.141
Locomotion	273	< 0.001
Maintenance	231	< 0.001
Reproductive behavior	401.5	0.003
Scent marking	399	0.008
Solitary play	296	0.03
Stereotypic pacing	NA	NA

The "Affiliative" and "Agonistic" Categories consisted of many individual behavior types (Figure 4,5). Comparative graphs were produced to show how the proportions of these behaviors differed between the two species [19,20]. Body contact and laying next to another individual were the most commonly seen behaviors, though occurred at a greater proportion for lions than for tigers. Baring teeth occurred more in tigers than lions and biting occurred more in lions than tigers.

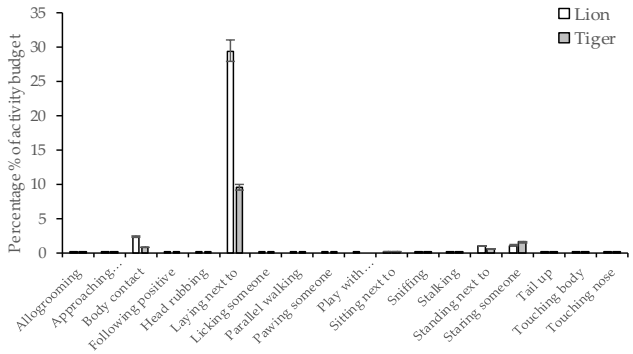

Figure 4: Comparison of lion and tiger affiliative behaviors (+/- standard error).

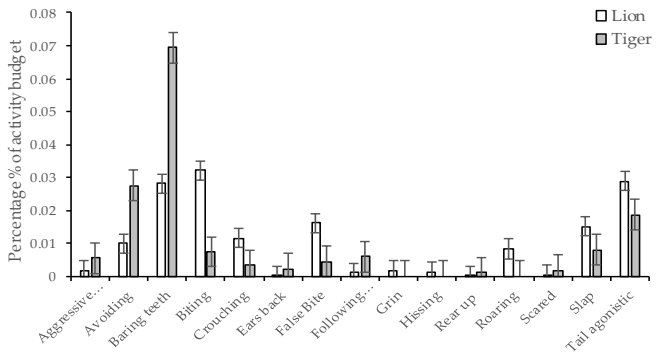

Figure 5: Comparison of lion and tiger aggressive behaviors (+/- standard error).

Social networks

Association indices were generated for each pair of felids. The minimum possible value was 0, where two individuals were never seen in close proximity, and 1, where the individuals were always observed in close proximity. The average association indices (AAI) were 0.0146 and 0.0127 for the lion pride and tiger group respectively, indicating higher association rates in lions.

Social network maps were generated using Netdraw for both species (Figures 6 and 8). Both networks were filtered using their respective AAI scores, to remove weak associations that were likely to have occurred by chance. Both maps were filtered again, using an association index of 0.05, to remove all but the strongest associations (Figures 7 and 9).

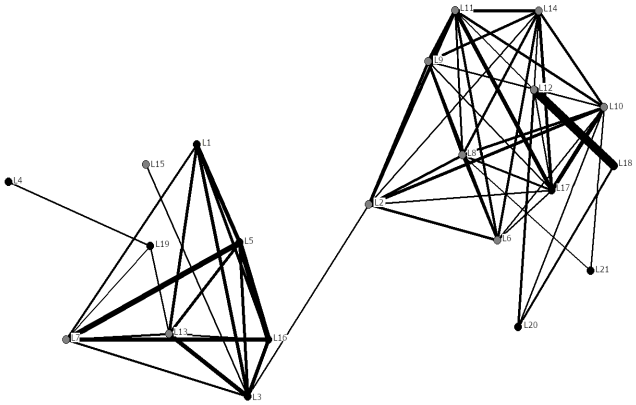

Figure 6: Lion social network, filtered using the tiger AAI of 0.0146. Grey and black nodes represent males and females respectively. Association strength is portrayed by the thickness of the edge.

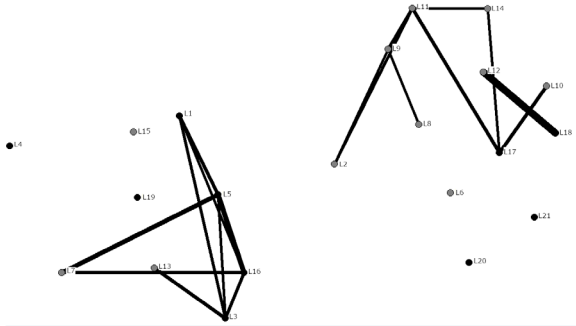

Figure 7: Lion social network, filtered using a stronger association index of 0.05, to remove all but the strongest relationships. Grey and black nodes represent males and females respectively. Association strength is portrayed by the thickness of the edge.

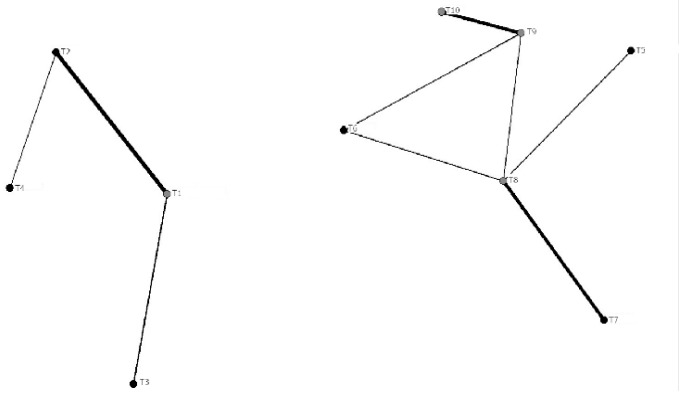

Figure 8: Tiger social networks filtered using the tiger AAI of 0.0127. Grey and black nodes represent males and females, respectively. Association strength is portrayed by the thickness of the edge.

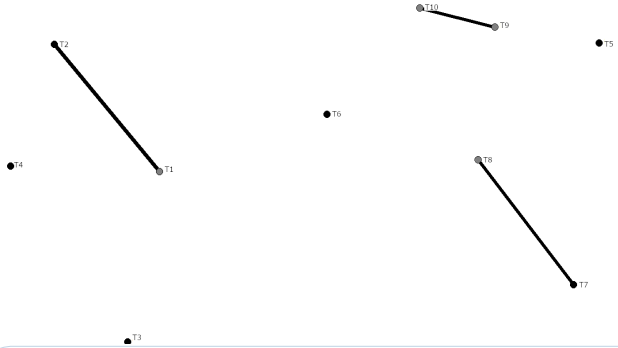

Figure 9: Tiger social networks filtered using a stronger association index of 0.05, to remove all but the strongest relationships. Grey and black nodes represent males and females, respectively. Association strength is portrayed by the thickness of the edge.

The occurrence of affiliative interactions (Figures 10 and 11) were then mapped using Netdraw. These networks were not filtered as the occurrence of behaviors were rare.

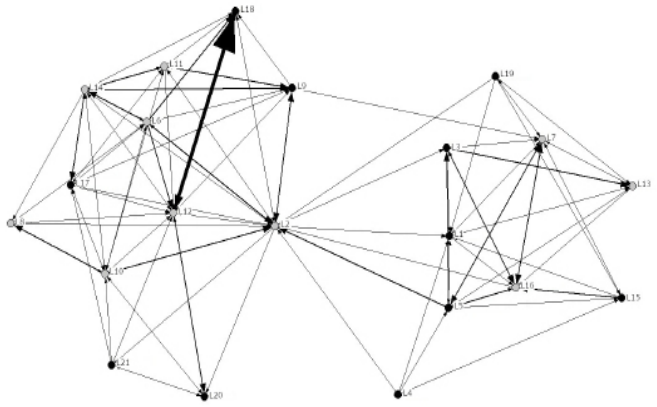

Figure 10: Affiliative behaviors between lions. Grey and black nodes represent males and females, respectively. Association strength is portrayed by the thickness of the edge.

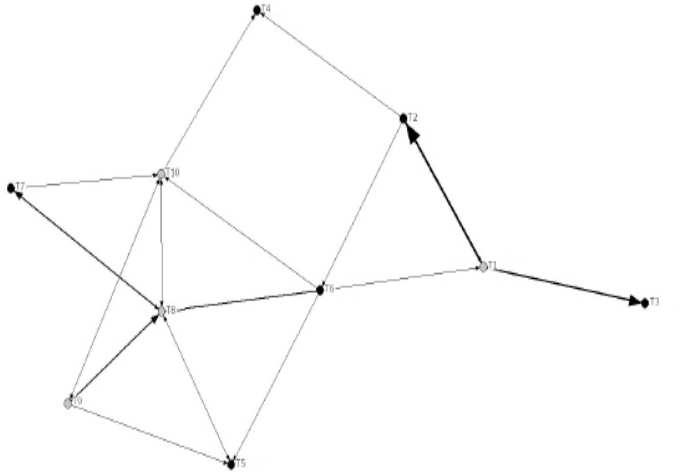

Figure 11: Affiliative behaviors between tigers. Grey and black nodes represent males and females, respectively. Association strength is portrayed by the thickness of the edge.

Enclosure use

The zone use of all individuals was summarized and converted into percentages. Lions often used the same enclosure zones, as shown by the shared use of the central zone and near inside zone (Figure 12). There appeared to be two general groups of tigers; the two groups did not tend to share resources with each other. The tigers appeared to have very few shared enclosure zones, with pairs and trios of animals using only a few zones during all observations (Figure 13).

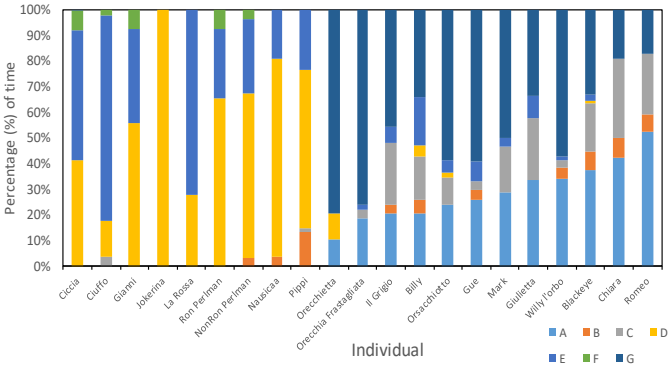

Figure 12: Use of enclosure zones by individual lions. Refer to Table 3 for zone names.

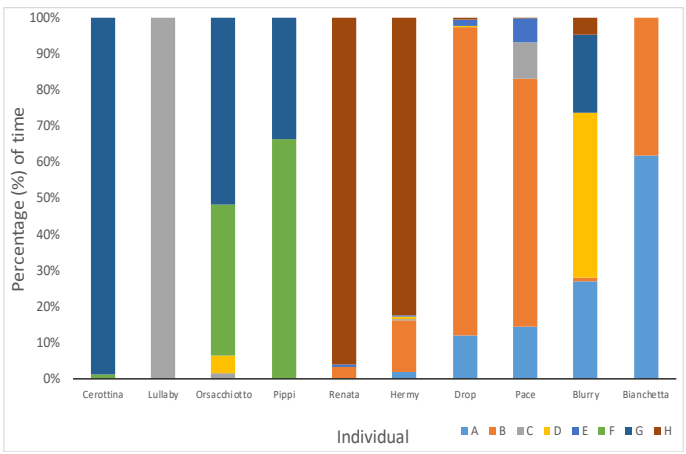

Figure 13: Use of enclosure zones by individual tigers. Refer to Table 3 for zone names.

Discussion

This study revealed that felids at the Zoo Safari of Fasano did not often manifest undesirable behavior, the observed behavior profiles were similar to those of other captive *Panthera* [24,25]. Although captive felids display stereotypic behaviors (e.g. pacing) [16] stereotypy expression in this study was low: lions did not show any stereotypic behaviors and for tigers this behavioral occurred rarely. Visitor presence has been shown to influence zoo animal behavior in previous research [26,27,28] but was not shown to affect stereotypy in this study. Stereotypy is typically associated with stress and is considered by some authors to be a 'coping mechanism' for animals. It is promising therefore that the animals did not show excessive evidence of stereotypy during the study.

Felids are often housed in pairs in zoological collections [5,28,29]. The results of this study provide an initial glimpse into the potential welfare and sociality implications of group housing [30,31]. There are known benefits for group housing, especially in terms of space for *ex situ* conservation of endangered species such as the tiger. However, potential welfare issues and compatibility must be taken into account before any type of social situation is considered.

For lions, social grouping could replicate the natural social condition that takes place in the wild. The Zoo Safari of Fasano may provide enough space to host two well defined prides within a single enclosure [32]. The enclosures studied were both very large in comparison to typical zoos enclosures. Both exhibits also included refugia, trees, shrubs and ponds, along with shaded areas that could help the animals to not express undesirable behaviors linked to the temperatures recorded [33].

The analysis of the categories for each subject was useful to see the differences between the individuals within each group. Several key differences emerged between their affiliative, agonistic, proximity behaviors and in the complexity of their social structure. Agonistic events were few and this category occupied less than 0.10 percent of the time budget. When agonistic behavior was observed, it was generally relatively minor.

A male-female pair (L12, L18) showed the strongest links in both the affiliative and agonistic social networks. Their relationship could be somehow associated with reproductive interests, due to the fact that all the lions hosted are non-neutered and could mate whenever and whoever they prefer, and during the observation period this couple was potentially mating, expressing not exclusively reproductive behaviors but also social behavior [22,32].

The possible choice of a mating partner recreates the natural condition of a pride, but the absence of cubs and juveniles prevent infanticide and consequently aggressive behavior, so in a controlled environment such as this safari, maintained non-neutered individuals is possible. Non-neutered groups are useful for ethological research, animals show all the behavioral spectrum, but obviously those condition preclude structures like the one studied from reproduction and reintroduction programs due to the mixed lineage of individuals.

The head rubbing behavior [18] was descriptively analysed due to its importance in social bonding both in lions and tigers, but not included in the results due to the data type. For lions, males head rubbed other males more often than females. This might link to the affiliation in male coalitions as in the wild [5,10] and may have reduced aggression between males.

The head rubbing in tigers was less present than in lions, due to the fact that there were less interactions between the subjects. Tigers may use a wider range of non-contact communication techniques (such as chuffing) that may be used instead of contact, but were not recorded in this study. The investigation of zone use in tigers showed that tigers tended to spend time in pairs. One female (T4) preferred to spend her time in only one zone, alone, this was related to a possible pregnancy.

"Exploratory" and "Inactive Behaviors" occurred at similar proportions for both groups and this is in line with literature about those species [5,10]. The category Affiliative behavior occurred significantly more often in lions ($P< 0.001$), underlying the stronger sociality of this species and the needs of social bonds even in captivity.

Marking and reproductive behavior occurred more frequently in lions. Both the presence of a large number of males [11] and the division in the two sub-groups, could be valid explanations for the amount of marking behaviors (comprehending also the vocalization coughing), expressing their territorial and social nature.

Locomotion occurred more in tigers, reflecting their natural behaviors, such as patrolling that in wild is widely described [27]. Also, the category Maintenance occurred more in tigers, for example bathing is considered their remedy to control high temperatures with thermoregulation [21]. Noel et al. [33] demonstrated in six species of felids, that with self-grooming, the saliva evaporation could cooling the temperature of the animal body so this could be an explanation of the big expression of self-grooming by tigers in this study. Thus, considering also the few events of pacing, all this behaviors could represent their way to managed their own welfare [34].

A deeper analysis in the affiliative and agonistic categories remarked that no statistical tests were possible for the lack of data. The affiliative behaviors more expressed was laying next to in lions, and for the agonistic behaviors was baring teeth in tigers. It is important to identify that biting was the most intense aggressive behavior occurred during the observations, expressed more by lions, reflecting how weak were the episodes of aggressions [35].

Social networks and enclosure use

The analysis of proximity data revealed social substructures to both the lion and tiger groups. On average, lions had a slightly stronger association index, indicating that they were more likely to spend time in close association with other individuals. This result is to be expected, given the wild pride group structure for the species [15,21,29].

However, it should be noted that the social network did not in fact reveal just one pride, but two prides of lions which showed strong definition in terms of their membership. When filtered using the AAI to remove very weak relationships, only two lions showed any association with individuals from the other pride. When filtered using a stronger association index, this single connection between the prides disappeared.

It is surprising to see evidence that two separate prides might exist in the same exhibit, especially with minimal levels of aggression. However, the large size of the safari exhibit may allow the two prides to coexist with minimal interaction with one another. The two prides appear to have their own specific

exhibit zones, which do not appear to be used by individuals from the other pride. Zone use data suggests that there are few communal zones that are used by both prides [30]. In terms of welfare and behavior, lions may therefore not need to adjust their behavior or adopt coping mechanisms to deal with the presence of another pride, provided they have sufficient space to adopt their own space [31,32].

For tigers, the results are more complex. An initial social network revealed two subgroups (four and six individuals) with only weak relationships between the two. However, when filtered using a stronger association index, most of the associations within the groups disappeared, leaving pairs of tigers, and singletons. This suggests that in comparison to the lions, tigers were less likely to spend time in close proximity to others, and they typically had one or no favored individuals to spend their time with. These pairs consisted of two male-female associations and one male-male association. This tendency for tigers to form smaller social groups may be a reflection of their wild state as generally solitary animals [5].

The preponderance of paired associations, however, is interesting to note. There is some evidence to suggest that some supposedly solitary big cats such as leopards might tolerate other individuals, particularly in environments where food is plentiful [12]. Here, the social network might actually identify that tigers have selected favored conspecifics to spend their time with.

For tigers, enclosure use showed that there are few communal enclosure zones, and that two or three individuals might share one exhibit area. The exhibit size here may be a key factor: pairs, trios and singletons spend the majority of their time in a few exclusive zones, and tend to avoid other individuals. The large safari enclosure may make this possible, as individuals have sufficient space to choose their conspecifics and areas to avoid [33]. This seems to correlation with previous research: comparisons of tiger behavior in different sized exhibits suggested that those in the smallest enclosures were more likely to stereotype [34].

Future directions

This study identified different group structures between group-housed lions and tigers. The relatively minimal evidence of aggression and stereotypy is initially promising. To develop this topic, a wider range of welfare measurements could be used to assess the animals. Furthermore, more research is necessary before this can be rolled out more widely in captivity.

Future directions include analysis of behavior, sociality and enclosure use over an extended time period to take into account seasonal effects. Unfortunately, it was not possible to conduct this for the current study due to the different management during winter period for the lions and tigers.

Studies should also consider the potential confounding effects of felid species [5]. For example, the current study has evaluated the suitability of group housing for lions and tigers, both of which are closely related and in the *Panthera* genus [5]. Similar studies could investigate whether other felids are also being held in groups in enclosures, and whether similar behavioral effects occur.

A new behavior called paw treading was observed in three lions and one tigress. While this behavior has not been reported in literature for adult big cats, it has been video recorded by amateurs for numerous pets (e.g. cats and dogs) and was seen also in a video on a social platform of an individual of snow leopard of the Big Cat Sanctuary (UK). It was interpreted here as a comfort behavior referred to the milk treading express by cubs to call the mother's milk during feeding.

Research into the wider prevalence of paw treading and a deeper analysis of individuals' personality traits are potential avenues for future studies.

Conclusion

As an exploration of the suitability of tigers for social housing, the conclusion is not clear cut. On one hand, aggression levels in the social-housed tiger group appear to be similar to a large pride of lions. On the other hand, tigers spent comparatively more time engaged in locomotion, maintenance behaviors such as grooming, and stereotypy was observed only in tigers, not in lions. Some of these behaviors might be suggestive of avoidance of conspecifics: investigations of sociality seem to suggest this, as tigers on the whole had weaker associations, and tended to associate only with a couple of individuals. A large, safari-style exhibit may have allowed tigers to tolerate one another and choose to associate with only one or two conspecifics. Ideally, more research into this area would be beneficial and at current, this study attempts to investigate potential welfare impacts. Small social groups consisting of pairs and trios may also be effective as a housing strategy for captive tigers. Further studies, particularly those comparing solitary, pairs and socially-housed tigers would help to investigate this topic to inform husbandry recommendations.

Investigation of sociality revealed that the lion group actually consisted of two well-differentiated prides, and there was minimal social interaction between the two groups. However, aggression levels remained minimal across the groups, suggesting that multiple social groups can coexist in an exhibit, provided they have enough space to establish their own zones.

References

1. Rose PE, Brereton JE, Rowden LJ, de Figueiredo RL, Riley LM. What's new from the zoo? An analysis of ten years of zoo-themed research output. Palgr. Comm. 2019; 5: 1-10.
2. Melfi VA. There are big gaps in our knowledge, and thus approach, to zoo animal welfare: A case for evidence-based zoo animal management. Zoo Biol. 2009; 28: 574-588.
3. Pastorino GQ, Preziosi R, Faustini R, Curone G, Albertini M, et al. Comparative Personality Traits Assessment of Three Species of Communally Housed Captive Penguins. Anim. 2019; 6: 376-389.
4. IUCN. Available onlinehttps://www.iucnredlist.org/species/159951/115130419 (Accessed on 10 Apr 2020).
5. Macdonald D, Loveridge A. The biology and conservation of wild felids, 2nd ed.; Oxford University Press: Oxford, UK. 2010; 154-256.
6. Lacy RC. Achieving true sustainability of zoo populations. Zoo Biol. 2013; 32: 19-26.
7. Blomqvist L. Three decades of Snow leopards Panthera uncia in captivity. Int. Zoo Year. 1995; 34: 178-185.
8. Species 360. Available online https://zims.species360.org/Main.aspx (accessed on 12 April 2020).
9. Wharton D, Mainka SA. Management and husbandry of the Snow leopard Uncia uncia. Int. Zoo Year. 1997; 35: 139-147.

10. Spong G. Space use in lions, Panthera leo, in the Selous Game Reserve: Social and ecological factors. Behav. Ecol. Socio. 2002; 52: 303-307.

11. Chakrabarti S, Jhala YV. Selfish partners: Resource partitioning in male coalitions of Asiatic lions. Behav. Ecol. 2017; 28: 1532-1539.

12. Pirie TJ, Thomas RL, Reilly BK, Fellowes, M.D. Social interactions between a male leopard (Panthera pardus) and two generations of his offspring. Afr. J. Ecol. 2014; 52: 574-576.

13. Baker K, Pullen K. The impact of housing and husbandry on the personality of cheetah (Acinonyx jubatus). J. Zoo Aq. Res. 2013: 1: 35-40.

14. Marker-Kraus L, Grisham J. Captive breeding of cheetahs in North American zoos: 1987–1991. Zoo Biol. 2003; 12: 5-18.

15. Spong G, Creel S. Effects of kinship on territorial conflicts among groups of lions, Panthera leo. Behav. Ecol. Socio. 2004: 55: 325-331.

16. Kroshko J, Clubb R, Harper L, Mellor E, Moehrenschlager A, et al. Stereotypic route tracing in captive Carnivora is predicted by species-typical home range sizes and hunting styles. Anim. Behav. 2016; 117: 197-209.

17. Lyons J, Young RJ, Deag JM. The effects of physical characteristics of the environment and feeding regime on the behavior of captive felids. Zoo Biol. 1997; 16: 71-83.

18. Martin P, Bateson P. Recording methods. In 'Measuring Behaviour: An Introductory Guide'. 2nd ed.; Oxford University Press: Oxford, UK. 2007.

19. Stanton LA, Sullivan MS, Fazio JM. A standardized ethogram for the felidae: A tool for behavioral researchers. Appl. Anim. Behav. Sci. 2015; 173: 3-16.

20. Pastorino GQ, Viau A, Curone G, Pearce-Kelly P, Faustini M, et al. Role of personality in behavioral responses to new environments in captive Asiatic lions (Panthera leo persica). Vet. Med. Int. 2017; 24-36.

21. Mosser A, Packer C. Group territoriality and the benefits of sociality in the African lion, Panthera leo. Anim. Behav. 2007: 78: 359-370.

22. Croft DP, James R, Kraue J. Exploring Animal Social Networks. Princeton: Princeton University Press. 2008.

23. Borgatti SP. NetDraw Software for Network Visualization. Analytic Technologies: Lexington, KY. 2007.

24. Smith JLD, McDougal C. The Contribution of Variance in Lifetime Reproduction to Effective Population Size in Tigers. Cons. Biol. 1991; 5: 484-490.

25. Phillips C, Peck D. The effects of personality of keepers and tigers (Panthera tigris tigris) on their behaviour in an interactive zoo exhibit. Appl. Anim. Behav. Sci. 2007; 106: 109-116.

26. Rose PE, Scales JS, Brereton JE. Why the "Visitor Effect" Is Complicated. Unraveling Individual Animal, Visitor Number, and Climatic Influences on Behavior, Space Use and Interactions With Keepers-A Case Study on Captive Hornbills. Fron. Vet. Sci. 2020; 7: 236-247.

27. Carlstead, K. "Effects of captivity on the behaviour of wild mammals", in D.G. Kleiman, M. Allen, K. Thompson, S. Lumpkin, Wild Mammals in Captivity: Principles and Techniques, Chicago, IL: University of Chicago Press. 1996.

28. Hosey G, Melfi V, Pankhurst S. Zoo animals: Behaviour, management, and welfare, Oxford, Oxford University Ptress. 2009.

29. Margulis SW, Hoyos C, Anderson M. Effect of felid activity on zoo visitor interest. Zoo Biol. 2003; 22: 587-599.

30. De Rouck M, Kitchener AC, Law G, Nelissen M. A comparative study of the influence of social housing conditions on the behaviour of captive tigers (Panthera tigris). Anim. Wel. 2005; 14: 229-238.

31. Miller A, Kuhar CW. Long-term monitoring of social behavior in a grouping of six female tigers (Panthera tigris). Zoo Biol. 2008; 27: 89-99.

32. Brereton JE. Directions in animal enclosure use studies. J. Zoo Aquar. Res. 2020; 8: 1-9.

33. Noel AC, Hu DL, Cats use hollow papillae to wick saliva into fur. Proc. Nat. Acad. Sci. 2018; 115: 12377-12382.

34. Pastorino GQ, Paini F, Williams CL, Faustini M, Mazzola SM. Personality and Sociality in Captive Tigers (Panthera tigris). An. Res.& Rev. Biol. 2017; 21: 1-17.

35. Pastorino GQ, Christodoulides Y, Curone G, Pearce-Kelly P, Faustini M, et al. Behavioural profiles of brown and sloth bears in captivity. Animals. 2017; 7: 39.