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SHORT COMMUNICATION

The unique case of marking behaviour in juvenile lynx

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Abstract

Active scent marking with urine has been described in a number of mammal species, including felids. In Eurasian lynx (*Lynx lynx*), scent marking plays a role in intra-sexual competition and territory defence as well as in attracting sexual partners during the mating season. Marking is most frequent during the mating season and least frequent during the period when females give birth and lactate. Males generally mark more frequently than females and resident animals mark more frequently than dispersers. Juveniles have never been recorded actively marking. Here, however, we present a well-documented case of an actively marking juvenile lynx. Lynx females Koka and Baronka were born in 2019 to mother Nela, who disappeared in December 2019. Nela's territory stayed vacant, with her juvenile daughters being the only females recorded there. On the 30th March 2020, during the mating season, Koka was recorded on a camera trap video actively marking with urine, rubbing her face and again marking with urine on a rock. On the following day, she again marked with urine on the same marking site. After that, Koka left the area and the former territory of Nela was taken over by Baronka. In the BBA lynx population, juvenile lynx females were documented to successfully reproduce. This poses the question of whether their adult-like marking behaviour should be explained in the context of early reproduction, or if it has other reasons. Neither Koka nor Baronka successfully reproduced with the local male during their first year of life, but that does not mean they did not try to attract him by marking. Also, juveniles' competition over the territory left vacant by their mother is a feasible explanation. We suggest that high population turnover may result in unusual social situations, with juveniles consequently performing unusual behaviour. This does not have to be related to early reproduction.

Keywords Eurasian lynx · *Lynx lynx* · Scent marking · Behaviour · Juvenile · Orphan · Bohemian-Bavarian-Austrian lynx population · BBA

Article

Mammals are complex social creatures, who are known to communicate visually, acoustically, and also by odours (Halpin 1986; Kean et al. 2017; Campbell-Palmer and Rosell 2011). These so-called "social odours " may carry information about the animal's sex, reproductive status, individual identity, territory ownership, dominance, and health status (Johson 1973; Brennan and Kendrick 2006; Wyatt 2003; Vogt et al. 2016). They consist of complex mixtures of molecules sensed by chemosensory systems and have important influences on a variety of behaviours that are vital for reproductive success, such as parent–offspring attachment, mate choice, and territorial marking (Johson 1973, Brennan and Kendrick 2006; Wyatt 2003; Vogt et al. 2014). In many mammal species, the development of scent glands and the offset of marking behaviour corresponds with the sexual maturity of animals (Johnson 1973). In other cases, however, the triggers of scent marking are still unclear (Ewer 1968; Allen et al. 2016).

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Active scent marking with faeces and urine has been described in several mammal species (reviewed in Gosling and Roberts 2001a, b), including felids (Mellen 1993; Mohorović and Krofel 2020; Asa 1993; Vogt et al. 2014; Sæbø 2007; Stromková 2020). Despite intensive research on this topic in recent years, the basic information on scent marking is lacking for 23% of all felid species, and information on 21% of other felid species comes solely from a single study in captivity (Allen et al. 2016).

In tigers, females mark intensively prior to oestrus but not during it, and males mark most frequently when females are in oestrus (Smith et al. 1989). Marking is the most intensive when tigers are establishing territories (Smith et al. 1989). In pumas, scent communication at community scrapes is used by females to select dominant resident males to mate with, while males advertise themselves for mating and try to deter competitors (Allen et al. 2014; Allen et al. 2015). Dependent kittens do occasionally mark at community scrapes, but generally do not exhibit this behaviour, probably because they have no need to establish territories nor advertise availability to mate (Allen et al. 2021).

Small cats (*Felinae*) exhibit strong uniformity in both scent marking and social behaviours (Mellen 1993). Reproductively active animals mark more frequently than others, especially during oestrus (Mellen 1993). In a female black-footed cat, the marking frequency peaked before the mating season and was absent during the period of rearing of young, thus advertising female reproductive status (Molteno et al. 1998). In the bobcat, marking is primarily exhibited by adults (Bailey 1974), although juveniles were found to mark from 5 months of age (Wassmer et al. 1988). In both bobcat and Iberian lynx, scent marking seems to mainly play a role in territory defence, while its connection to mating behaviour is not yet clear (Wassmer et al. 1988; Bailey 1974; Beltran et al. 1987; Barja et al. 2005).

The Eurasian lynx (hereafter: lynx) is known to scent mark with urine at visually conspicuous sites such as rocks, fallen tree trunks, roots, wood piles, wooden cabins, and along frequented lynx paths, where it is probable that conspecifics will find the scent mark (Allen et al. 2017; Sæbø 2007; Vogt et al. 2014; Stromková 2020; Krofel et al. 2017). Faeces are also frequently found exposed at marking sites, although at resting sites or nearby kill lynx usually hide them (Sæbø 2007; Stromková 2020, own unpublished data). Marking behaviour is not equally distributed in time but is most frequent during the mating season (January-April) and least frequent during the period when females give birth and lactate (May–July) (Vogt et al. 2014). Males mark more frequently than females (Vogt et al. 2014; Sæbø 2007; Stromková 2020). Juveniles visit marking sites with their mothers, but according to the three large-scale scent marking studies of Alpine, Scandinavian, and Carpathian lynx populations (Vogt et al. 2014; Sæbø 2007; Stromková 2020), lynx juveniles have never been observed actively marking. Juvenile scent marking has not been previously recorded in the Bohemian-Bavarian-Austrian lynx population, either (own unpublished data).

When it comes to the social status of the animal, both residents and dispersing lynx were found to scent mark, however with different frequencies (Vogt et al. 2014; Sæbø 2007; Stromková 2020). Resident animals are found to mark the most, probably in order to defend their territories (Vogt et al. 2014; Sæbø 2007; Stromková 2020). In Scandinavia, adult lynx placed scent marks more often at the borders than in the centers of their home ranges (Sæbø 2007). In other regions, lynx females were observed to mark more often in core areas, where they spent most of their time (Gosling and Roberts 2001b; Wyatt 2003; Hucht-Ciorga 1988). Lynx marking behaviour is however not only related to intra-sexual competition and territory defence, but also plays an important role in attracting sexual partners during the mating season (Vogt et al. 2014).

The territorial behaviour of animals is generally considered to be determined mainly by food availability and distribution, which has a major impact on animal fitness, especially in females (Carpenter and MacMillen 1976; Maher and Lott 2000; McLoughlin et al. 2000; Adams 2001; Borger et al. 2008). In Eurasian lynx, prey availability strongly affects territory size (Mengüllüoğlu et al. 2021; Aronsson et al. 2016) and reproductive success in females (Yom-Tov et al. 2010; Nilsen et al. 2010). Lynx territoriality is also strongly dependent on the animal's social status, with age, sex, reproductive status, population density, and spatial distribution affecting the size and even the very existence of lynx territories (Mengüllüoğlu et al. 2021; Aronsson et al. 2016).

In the Bohemian-Bavarian-Austrian lynx population, the mean annual home range sizes are 438 km^2 for adult males and 278 km^2 for adult females (own unpublished data, Belotti et al. 2012; Magg et al. 2016; Wölfl et al. 2001). Generally, the home range of one male overlaps with those of one to three females (Mináriková et al. 2020; Wölfl et al. 2020; Engleder et al. 2019, 2021). Home ranges of adult lynx of the same sex may partially, but never entirely, overlap (Mináriková et al. 2020; Wölfl et al. 2020; Engleder et al. 2019, 2021).

Here we present a unique, well-documented case of an actively marking juvenile lynx.

It was recorded in the so-called Bohemian-Bavarian-Austrian (BBA) lynx population, whose distribution area stretches across the borders between the Czech Republic, Bavaria, and Austria (Fig. 1).

Camera trapping is used as a major lynx monitoring method in all three countries, complemented by snow tracking and genetic analyses. To space the camera traps evenly across the region, we used a 10 km × 10 km grid (ETRS LAEA 5210 10 km grid) and installed two to eight camera

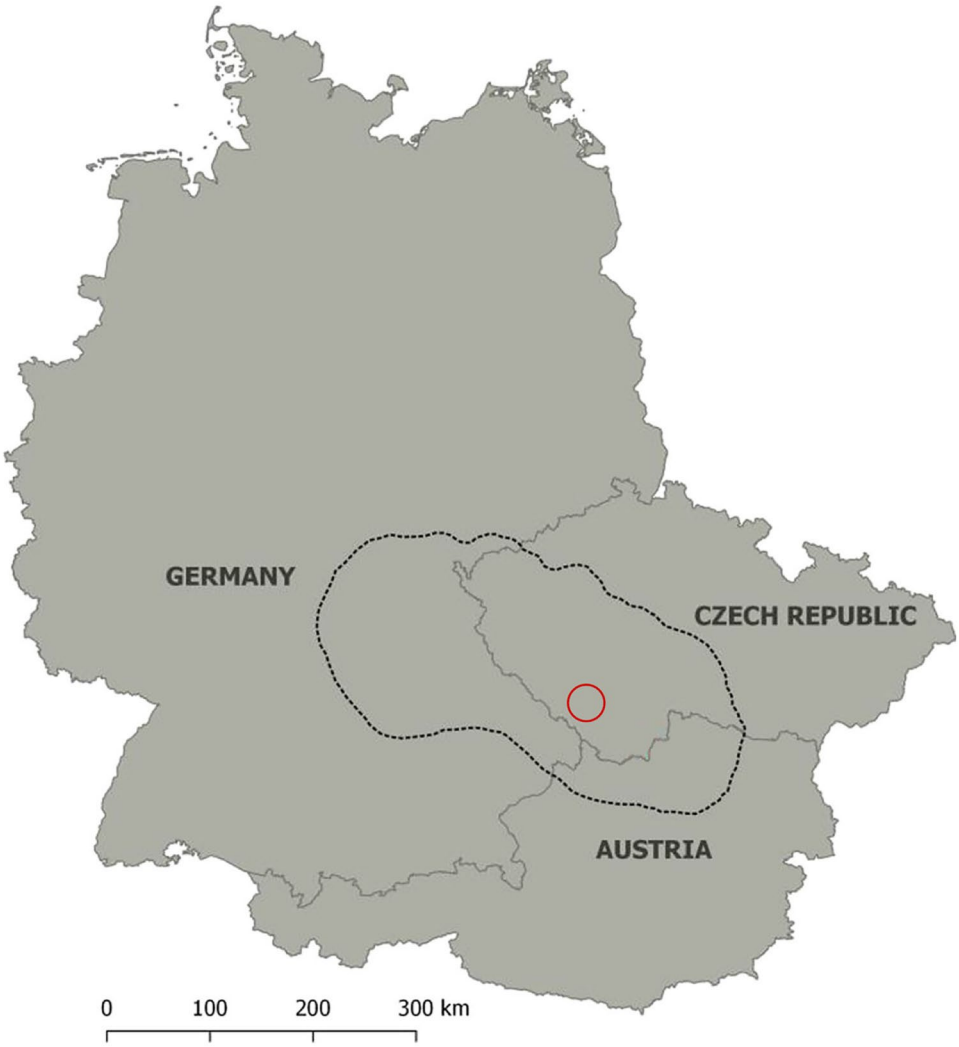

Fig.1 Map of Bohemian-Bavarian-Austrian lynx population. The wider region of Vlachovo Březí forests, where the yearling female Koka was documented, is circled in red

trapping sites per grid cell, depending on the area and habitat type. Altogether, 131 grid cells were covered by camera trapping in the years 2017–2021 as part of the 3Lynx project and following national activities (Mináriková et al. 2020; Wölfl et al. 2020; Engleder et al. 2021).

The time unit for data analysis was lynx year, that is the period starting on the 1st May and ending on the 30th April of the following year, based on the lynx life cycle (Mináriková et al. 2020). In the data analysis, the following categories were used for lynx according to their status:

- "Juvenile lynx"—lynx in the first year of life (also called "kitten"), recorded from birth till the 30th April of the following calendar year (0–1 year of age).
- "Subadult lynx"—lynx in the second year of life, recorded from the 1st May of the year following the birth till the 30th April of the next year (1–2 years of age).
- "Adult lynx"—lynx older than 2 years.
- "Independent lynx"—lynx older than 1 year, i.e., subadult or adult.
- "Resident lynx" lynx staying for minimally 12 months in the same area after becoming independent.

Lynx females B748 Koka and B749 Baronka were born in spring 2019 to B718 Nela, a resident female in the Vlachovo Březí area (Czech Republic, South Bohemian region, Fig. 1). They were born in the territory of resident male B716 Karlos.

Karlos and Nela both disappeared during the lynx year 2019 and have not been recorded since then, thus we assume they are dead. Karlos's territory was taken over by the subadult young male B740 Piškot in November 2019. Nela was last recorded with both her kittens on the 13th December 2019, but the exact date of her death remains unknown as she could have been missed by camera traps for some time. Her territory was not taken over by any subadult or adult

female. Therefore, both her juvenile daughters were left with the possibility of settling into the vacant territory they already inhabited as kittens.

On the 30th March 2020, during the mating season, Koka was recorded on a video actively marking with urine, rubbing her face, and again marking with urine on a marking site (Fig. 2). On the following day, she again marked with urine on the same spot (Fig. 3). On the 29th March this marking site was visited by Piškot and on the 2nd April it was visited by Baronka, but they were not recorded marking, they both merely inspected it. It was a rock, previously used for marking by resident female Nela, previous resident male Karlos, new resident male Piškot, and later Baronka.

Between the 3rd and 26th of April 2020, after the end of the mating season, Koka left the area and dispersed 40 km far to the Boletice military training area and then to the Protected Landscape Area Blanský les, where she has lived since July 2020. The former territory of Nela was taken over by Baronka, who is till now (December 2022) the resident reproducing female lynx here, sharing the area with male Piškot.

Lynx females are known to successfully reproduce from the age of 2 years (Breitenmoser-Würsten et al. 2007; Nilsson 2013; Nilsen et al. 2010, 2012; Kvam 1991). Juvenile lynx ovulation was recorded in Norway, but no juvenile pregnancy nor parturition was found (Kvam 1991). The BBA lynx population is, to the best of our knowledge, the only European lynx population where juvenile lynx females were documented to successfully give birth and raise kittens to independence (Engleder et al. 2019; Palmero et al. 2021, own unpublished data). This poses the question of whether the adult-like marking behaviour of a juvenile female lynx should be explained in the context of early reproduction or if it has other reasons.

While the marking behaviour in lynx generally serves both to attract conspecifics of the opposite sex and to mark the territory (Vogt et al. 2014), we cannot assess what was the main purpose of Koka's behaviour. Neither Koka nor Baronka successfully reproduced with the resident male Piškot during their first year of life but that does not mean they did not try to attract him (or any other male) by marking. Also, juveniles' competition over the territory left vacant by their mother is a possible explanation for the marking behaviour, with Baronka winning over and displacing Koka, who then dispersed to a new area.

The BBA lynx population has a high turnover of adult and subadult lynx, similarly to its neighbours – the Western Carpathian and the Alpine lynx populations (Wölfl et al. 2020; Duľa et al. 2021; Breitenmoser-Würsten et al. 2007). Specifically, 23% of adults and 44% of subadults vanish every year, especially in the outskirt part of the BBA population's distribution (Wölfl et al. 2020). This inevitably causes social instability, with territories changing their owners frequently and some areas being temporary without lynx reproduction or entirely without lynx presence (Mináriková et al. 2020; Wölfl et al. 2020; Engleder et al. 2021). This instability may result in unusual social situations, like the one presented in this paper, with juveniles consequently performing unusual behaviours.

Fig. 2 Juvenile female Koka actively marking with urine, rubbing her face and again marking with urine on a marking site (the 30th March 2020)

Fig. 3 Koka again marking with urine on the same marking site (the 31st March 2020)

It is possible that too early independence, caused by the disappearance of the mother, may trigger the scent marking behaviour in lynx juveniles. It is known for other mammals (e.g. wolves) that various behaviours related to the reproduction process can be suppressed by the presence of the mother (Mech and Boitani 2007). Another explanation may be that juvenile lynx do not scent mark, because they have no need to establish territories nor attract mating partners, as long as they are provided for by the mother (Stromková 2020; Allen et al. 2021).

In any case, juvenile scent marking does not necessarily have to be related to early reproduction. Juvenile mothers from the BBA population did not have to exclusively hold their own territory to successfully raise their offspring (Engleder et al. 2019, 2021; Mináriková et al. 2020; Wölfl et al. 2020) and, in this specific case, the availability of the territory to a juvenile female lynx and the presence of a mating partner was not enough for her to reproduce.

Successful reproduction of young lynx females is a complex process related to many factors—environmental, physiological, and social— with physiological readiness related to a certain body mass index probably being a key prerequisite for sexual maturity (Nilsen et al. 2010).

Even so, the cases of adult-like behaviour of juvenile lynx are interesting and should be followed in detail to better understand the mechanisms causing them. Finally, it would be particularly important to assess to what extent is the high human-induced mortality of lynx changing social behaviour and/or lynx population structure.

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Data availability The datasets analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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