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VIDEO ARTICLE

Patterns in bobcat (*Lynx rufus*) scent marking and communication behaviors

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Abstract Intraspecific communication by solitary felids is not well understood, but it is necessary for mate selection and to maintain social organization. We used motion-triggered video cameras to study the use of communication behaviors in bobcats (*Lynx rufus*), including scraping, urine spraying, and olfactory investigation. We found that olfactory investigation was more commonly used than any other behavior and that—contrary to previous research—scraping was not used more often than urine spraying. We also recorded the use of cryptic behaviors, including body rubbing, claw marking, flehmen response, and vocalizations. Visitation was most frequent during January, presumably at the peak of courtship and mating, and visitation become more nocturnal during winter and spring. Our results add to the current knowledge of bobcat communication behaviors, and suggest that further study could enhance our understanding of how communication is used to maintain social organization. Videos relating to the behaviors in this article are available at: http://www.momo-p.com/showdetail-e.php?movieid=momo141104bn01a, http://www.momo-p.com/showdetail-e.php?movieid=momo141104bn02a, http://www.momo-p.com/showdetail-e.php?movieid=momo141104lr01a, http://www.momo-p.com/showdetail-e.php?movieid=momo141104lr02a, http://www.momo-p.com/showdetail-e.php?movieid=momo141104lr03a and http://www.momo-p.com/showdetail-e.php?movieid=momo141104lr04a.

Keywords Scent marking · Bobcat · *Lynx rufus* · Scraping · Behavior · Communication

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Introduction

Communication is an important component of the study of animal behavior, but it can be difficult to study in cryptic species. Most solitary felids are difficult to observe, and studies of their scent marking and communication behaviors in wild populations are limited (but see Smith 1989; Allen et al. 2014). Felids use a variety of scent-marking behaviors for communication, including urine spraying, scraping, deposition of feces, claw marking, and body rubbing (Kleiman and Eisenberg 1973; Bailey 1974; Mellen 1993; Smith 1989; McBride and Sensor 2012; Allen et al. 2014). Scent marking is used for a variety of purposes by felids, including territorial maintenance and courtship (Kleiman and Eisenberg 1973; Baily 1974; Verberne and Leyhausen 1976; Mellen 1993; Logan and Sweanor 2001), and can be an especially important method of intraspecific communication for solitary species with spatially dispersed populations. The use of these behaviors varies among species (Mellen 1993), and sometimes between sexes of the same species (Allen et al. 2014), which necessitates species-specific studies to understand these behaviors and patterns in their use.

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Bobcats (*Lynx rufus*) are a small felid that is distributed throughout much of North America (Larivière and Walton 1997). Bobcats are generally solitary, except during courtship and when females are raising young (Bailey 1974; Larivière and Walton 1997). In California, bobcat courtship and mating occur from December through February and, due to a 63-day gestation period (Larivière and Walton 1997), parturition generally occurs from March through May (Moriarty and Riley 2011). Females raise young for approximately 9 months, and young of the year disperse as the mother prepares to mate (Larivière and Walton 1997). Bobcats have defined territories but often show a large degree of overlap among individuals (Bailey 1974; Lovallo and Anderson 1996), and territorial maintenance is thought to be one of the main uses of intraspecific scent marking.

Very little research has been done on communication behaviors in bobcats (but see Bailey 1974; Wassmer et al. 1988), but studies of communication behaviors can inform about seasonal activity patterns and other aspects of natural history, and can also be used to census populations. Scent marking is thought to be primarily used by adult bobcats (Bailey 1974), although juveniles begin exhibiting scent marking behaviors at 5 months of age (Wassmer et al. 1988). The most common form of scent marking is thought to be scraping (Wassmer et al. 1988), while urine spraying, deposition of feces, and anal gland secretions are also used (Bailey 1974; Wassmer et al. 1988). Other solitary felids exhibit many of the same communication behaviors, including olfactory investigation and flehmen response to investigate olfactory cues, use cheek rubbing, body rubbing, and claw marking for scent deposition, and use vocal cues to attract mates (Verberne and Leyhausen 1976; Mellen 1993). Although bobcats have not been observed using many of these behaviors (e.g., flehmen response, cheek rubbing, body rubbing, claw marking, and vocalizations), it is reasonable to assume they may exhibit each of these behaviors. Bailey (1974) reported no temporal pattern in visitation to scent marking areas or deposition of scat, although Wassmer et al. (1988) found that bobcats scent mark more frequently during the courtship season.

We used a novel technology, motion-triggered video cameras, to document bobcat activity and behaviors in areas used for scent marking by multiple carnivores. The use of motion-triggered video cameras allowed recording, direct observation, and analysis of bobcat communication behaviors, allowing us to test hypotheses and compare results to previous studies. We hypothesized that courtship and mating would have an important influence on visitation and behaviors (e.g., Bailey 1974; Wassmer et al. 1988), and we therefore expected visitation to be most frequent and duration of visit to be longest during winter. We also hypothesized that visitation in most seasons would occur in nocturnal or crepuscular hours when bobcats are active, but that during winter bobcats would visit throughout the day in order to find prospective mates. Based on Bailey (1974), we hypothesized that scraping and urine spraying would be the most frequently used scent marking behaviors, and that, based on Wassmer et al. (1988), scraping would be used more frequently than urine spraying. We also hypothesized that, because these areas are used for communication, olfactory investigation would be used in the same proportion as scent-marking behaviors.

Materials and methods

Study area

Our study included approximately 1,700 km^2 in the Santa Cruz Mountains of California (Fig. 1). The study area is bounded by the Pacific Ocean to the west, the cities of San Francisco and San Jose to the north, and Highway 101 to the east; an additional major highway (Highway 17) bisects the study area. Elevation ranged from sea level to 1,155 m, and the climate is best described as mild Mediterranean. Historical average daily high temperatures range from 15.5 to 24.4 °C and average daily low temperatures range from 3.9 to 11.1 °C. The annual rainfall varies from 58 to 121 cm, the majority of which occurred from November to April (Wilmers et al. 2013).

Field methods

Between May 2011 and July 2013, we used motion-triggered video cameras with infrared flash (Bushnell TrophyCam, Overland Park, KS, USA) to monitor the behaviors of species at 48 scent-marking areas called "community scrapes" (see Allen et al. 2014). Community scrapes are areas used for communication by the carnivore guild, which in our study area included pumas (*Puma concolor*), bobcats, coyotes (*Canis latrans*), gray foxes (*Urocyon cinereoargenteus*), striped skunks (*Mephitis mephitis*), and raccoons (*Procyon lotor*). We programmed cameras to record a 60-s video recorded at each trigger with a 1-s delay before becoming active again. During visits by bobcats, we recorded the duration of each visit and the occurrence of a variety of investigation and scent-marking behaviors (Table 1).

Statistical analyses

We used program R version 3.0.0 (R Core Team 2013) for all statistical analyses and, following R guidelines, we cited any associated packages used in analyses. In each analysis, we considered $p \leq 0.05$ significant.

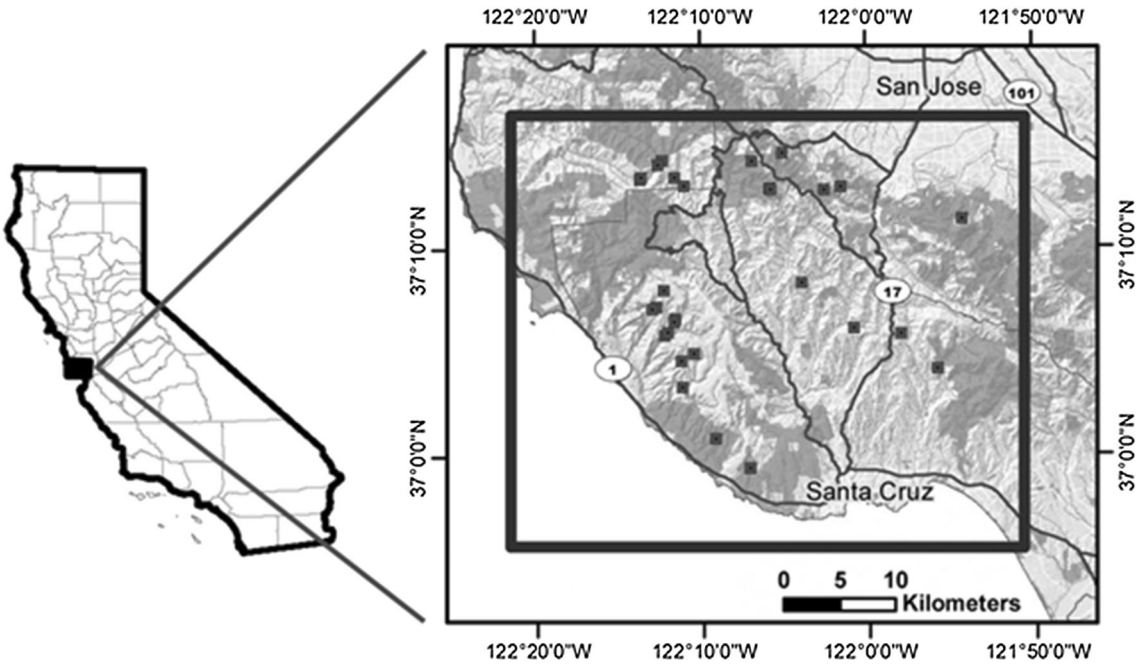

Fig. 1 A map of the study area, which included areas in the counties of Santa Cruz, San Mateo, and Santa Clara in California. The study area is outlined by the *thick black line*, within the greater context of major highways, and the cities of Santa Cruz and San Jose, and the location of each community scrape area monitored is noted

Table 1 Descriptions of behaviors exhibited by bobcats at community scrape areas

Behavior	Description of action	Occurrence (%)	Corresponding video
Body rubbing	The bobcat rubbed its cheek or shoulder on the ground or an object, or rolled back and forth on the ground. http://www.momo-p.com/showdetail-e.php?movieid=momo141104bn01a	0.4	1
Claw marking	The bobcat marked a standing or downed tree by scratching with its claws. http://www.momo-p.com/showdetail-e.php?movieid=momo141104bn02a	0.2	2
Flehmen response	The bobcat picked up its head and curled back its upper lip, and used its vomeronasal organ to investigate a signal or cue. http://www.momo-p.com/showdetail-e.php?movieid=momo141104lr01a	0.4	3
Olfactory investigation	The bobcat used its olfactory sense to investigate cues and signals, noted by the bobcat's nose within 15 cm of a scrape or other cue. http://www.momo-p.com/showdetail-e.php?movieid=momo141104lr02a	38.5	4
Scraping	The bobcat scraped in substrate with their hind feet and then sometimes urinated and/or defecated on the scraped mound of material. http://www.momo-p.com/showdetail-e.php?movieid=momo141104lr03a	13.3	5
Urine spraying	The bobcat squatted or backed up against an object or the ground and urinated. http://www.momo-p.com/showdetail-e.php?movieid=momo141104lr04a	11.7	6
Vocalizations	The bobcat exhibited use of any vocalization	0.2	–

The percentage of visits in which each behavior was exhibited is noted, and videos of each behavior are available in the Appendix, and are labeled by number

We tested for seasonal variation in bobcat visitation behaviors using calendar seasons (winter, spring, summer, and autumn). For these analyses we used the 24 community scrapes that we monitored for at least 1 year. We first modeled visitation in a generalized linear model with a Poisson link, using the number of visits as our dependent variable and season as our predictor variable. Second, we modeled the duration of visit in a generalized linear model with a Poisson link, using duration of visit as our dependent variable and season as our predictor variable. Third, we

analyzed the frequency of visitation in different time periods (10:00 pm–1:59 am, 2:00 am–5:59 am, 6:00 am–9:59 am, 10 am–1:59 pm, 2:00 pm–5:59 pm, 6:00 pm–9:59 pm) using a 2 × 6 chi-square test (Sokal and Rohlf 1987).

Next, we determined if bobcats varied in the frequency they used communication behaviors, or if the frequency of use of behaviors varied among seasons. First, we analyzed each behavior against every other behavior using 2 × 2 chi-square tests (Sokal and Rohlf 1987). We then calculated post hoc effect sizes for behaviors with significant statistical differences by calculating φ coefficients (Yule 1912) using the vcd package (Meyer et al. 2013), and we considered scores of 0.10 to be small effects, 0.30 to be medium effects, and 0.50 to be large effects (Cohen 1992). Second, we analyzed the frequency of each behavior among different seasons using a 2 × 4 chi-square test (Sokal and Rohlf 1987).

Results

We recorded 496 visits by bobcats. Visitation occurred throughout the year, with a peak in January, but visitation did not vary among seasons ($df = 3, 205$, $F = 0.17$, $p = 0.9150$) (Fig. 2). The duration of visitation had a mean of 18.7 (±1.4 SE) seconds, and did not vary among seasons ($df = 3, 205$, $F = 0.28$, $p = 0.8378$). Visitation by time of day varied among seasons ($df = 5, 204$, $\chi^2 = 33.06$, $p < 0.0001$); with visitation in winter and spring being more frequent during nocturnal time periods while visits in summer and autumn were more evenly distributed among all time periods (Fig. 3).

Olfactory investigation was exhibited during 38.5 % of visits (Table 1, http://www.momo-p.com/showdetail-e.php?movieid=momo141104lr02a), and was more frequently displayed than scraping ($\chi^2 = 80.75$, $p < 0.0001$, $\phi = 0.29$), urine spraying ($\chi^2 = 93.4$, $p < 0.0001$, $\phi = 0.31$), body rubbing ($\chi^2 = 227.4$, $p < 0.0001$, $\phi = 0.48$), flehmen response ($\chi^2 = 227.4$, $p < 0.0001$, $\phi = 0.48$), vocalizations ($\chi^2 = 230.7$, $p < 0.0001$, $\phi = 0.49$), or claw marking ($\chi^2 = 230.7$, $p < 0.0001$, $\phi = 0.49$). Scraping was exhibited during 13.3 % of visits (Table 1,http://www.momo-p.com/showdetail-e.php?movieid=momo141104lr03a), and was more frequently displayed than body rubbing ($\chi^2 = 80.7$, $p < 0.0001$, $\phi = 0.26$), flehmen response ($\chi^2 = 80.7$, $p < 0.0001$, $\phi = 0.26$), vocalizations ($\chi^2 = 87.1$, $p < 0.0001$, $\phi = 0.27$), or claw marking ($\chi^2 = 87.1$, $p < 0.0001$, $\phi = 0.26$). Scraping was not significantly different than urine spraying ($\chi^2 = 0.5$, $p = 0.5016$). When exhibiting scraping behavior, bobcats created 1 scrape at 93.9 % of visits and 2 scrapes during the other 6.1 % of visits. Urine spraying was exhibited during 11.7 % of visits (Table 1, http://www.momo-p.com/showdetail-e.php?movieid=momo141104lr04a), and was more frequently displayed than body rubbing ($\chi^2 = 53.7$, $p < 0.0001$, $\phi = 0.24$), flehmen response ($\chi^2 = 53.7$, $p < 0.0001$, $\phi = 0.24$), vocalizations ($\chi^2 = 56.5$, $p < 0.0001$, $\phi = 0.25$), or claw marking ($\chi^2 = 56.5$, $p < 0.0001$, $\phi = 0.24$). Neither scraping nor urine spraying varied significantly among seasons, although post hoc power analyses revealed that we did not have a large enough sample size to achieve statistical significance. There were no significant differences in the display of body rubbing (0.4 % of visits, http://www.momo-p.com/showdetail-e.php?movieid=momo141104bn01a), flehmen response (0.4 % of visits, http://www.momo-p.com/showdetail-e.php?movieid=momo141104lr01a), vocalizations (0.2 % of visits), or claw marking (0.2 % of visits, http://www.momo-p.com/showdetail-e.php?movieid=momo141104bn02a) (Table 1).

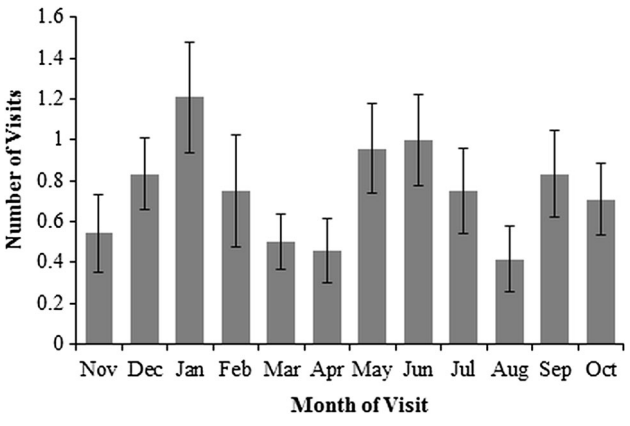

Fig. 2 Mean number of visits to each community scrape during each month of year. We used the first year of monitoring for the 24 areas that we monitored continuously for at least an entire year

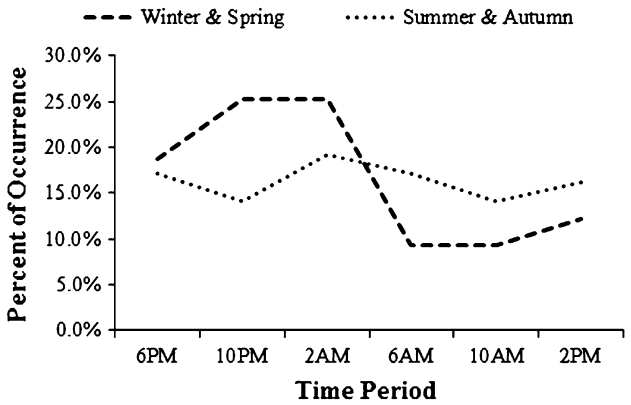

Fig. 3 Temporal visitation of bobcats by time period for each season. The day was broken into 4-h time periods, and visitation for each period is noted for the combinations of winter & spring and summer & autumn

Discussion

We documented that bobcats use a variety of behaviors for communication, and the use of video cameras allowed us to document that they occurred in different proportions than we expected. In contrast to previous studies (e.g., Wassmer et al. 1988), we found that scraping and urine spraying did not vary in their proportions of use. The physical scrapes created by felids are often the most obvious signs they leave on the landscape (Logan and Sweanor 2001; Allen et al. 2014), and this may have led to Wassmer et al. (1988) overestimating the occurrence of scraping in comparison to urine spraying, as urine spraying can be difficult to document in the field. Our monitoring of community scrapes may have overestimated scraping as well, as our observations from following individual bobcats suggest that urine spraying is more frequently used than scraping (Allen, unpublished data), suggesting there may be different uses for the two behaviors. Pumas, which do not use urine spraying, employ the physical scrape as a visual cue and use the accompanying urine to convey the signal (Allen et al. 2014). Alternatively, there may be specific objects bobcats prefer to spray urine on, and they may exhibit scraping behavior in the absence of these objects, or there may be a cue that triggers either scraping or urine-spraying behavior. We have also observed bobcats spraying urine on objects while traveling, and our documentation of communication behaviors at community scrapes may have underestimated their use of urine spraying in comparison to scraping behavior.

We found that olfactory investigation was more frequently used than other communication behaviors, but flehmen response was rarely used (0.4 % of visits). Olfactory investigation was used in 38.5 % of visits, more than scraping or urine spraying combined (25.0 %), suggesting that bobcats more frequently investigate than create scent. This suggests that territoriality may be based on familiarity with neighbors and less on exhibiting dominance through scent marking. Flehmen response was recorded on two occasions (0.4 % of visits), one of which was accompanied by the only vocalization we recorded, suggesting that bobcats display flehmen response behavior less frequently than other felids (Mellen 1993; Allen et al. 2014). Many carnivores use community scrapes, including pumas and coyotes that could injure or kill a bobcat, and bobcats may be spending a portion of their time using olfactory investigation for cues from other species as well as conspecifics.

We also documented the use of cryptic behaviors that were infrequently used, including body rubbing (0.4 % of visits) and claw marking (0.2 % of visits). Both cases of body rubbing were rolling behavior, where the bobcat rolled back and forth on the ground, and occurred at the same community scrape 8 days apart. Body rubbing in felids is generally used for the deposition of scent from the sebaceous gland (McBride and Sensor 2012), while claw marking is used by other felids as a visual sign that is investigated by other individuals (McBride and McBride 2010). Though both body rubbing and claw marking are used less frequently than scraping or urine spraying, they may also be used in specific instances and areas other than community scrapes, and hence may be used more frequently than we recorded. For example, female bobcats change their patterns of scent marking and scat deposition around natal dens (Bailey 1974; Wassmer et al. 1988), and because claw marking is used as a more permanent visual cue than scent marking (McBride and McBride 2010), it may be used in areas of more permanent residence. A combination of different cues are often used in mate selection (Candolin 2003), and the use and functions of these and other cryptic behaviors by bobcats is an area in need of further research.

We did not find as much support for seasonality influencing visitation and behaviors as we expected. Visitation was most frequent in January, which is likely the peak of courtship and mating (Larivière and Walton 1997), but visitation in winter did not vary significantly from other seasons. The lack of statistical significance may be due to our relatively low sample size rather than a biological difference. The timing of visitation did vary among seasons, but not as we hypothesized, as bobcats were more nocturnal in visits during winter and spring, and visits in summer and autumn occurred regularly in all time periods (Fig. 3). From a female perspective, this may be advanced preparation for giving birth, or females hunting predominately during the night when they have neonatal young. From the male perspective, it may be related to territorial behavior. For example, the killing of unfamiliar cubs and unreceptive females by males is a common form of mortality in many felids (Logan and Sweanor 2001; Balme and Hunter 2013), and perhaps male bobcats are actively protecting their territories and females they mated with during the spring from competing males. Our study was also based on community scrapes that are used by multiple carnivores, and this could have affected visitation and behaviors, with bobcats becoming more nocturnal to avoid interactions with dominant carnivores.

The use of motion-triggered cameras to document bobcats at community scrapes allowed us to advance our understanding of communication behaviors in bobcats. The main drawback of our study was not having marked individuals with known sex or identity. For example, in some felids, females do not regularly mark with urine except when in estrus (Verberne and Leyhausen 1976), and the bobcats we observed scent marking throughout the year may have only been males. Nevertheless, our results

challenge some previously held beliefs about scent-marking behaviors in bobcats and highlight the need for further study. Technology for research, including GPS collars and motion-triggered video cameras, has increased dramatically since previous research on bobcat scent-marking behaviors (e.g., Bailey 1974; Wassmer et al. 1988). A follow-up study with marked individuals of known sex would allow a direct examination of frequency of scent marking and the role of specific behaviors in courtship and territorial maintenance to be determined.

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