Changes in the reproductive behaviour of the endangered Newfoundland marten (*Martes americana atrata*): implications for captive breeding programs

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Abstract: Behavioural changes associated with reproduction were studied in captive Newfoundland martens (*Martes americana atrata*), an endangered species. Patterns of scent-marking and behavioural interactions were recorded before and after a male was introduced to two females. After introduction of the male, marking by the receptive female increased, whereas the nonreceptive female marked less and became less active. Activity and marking bouts were significantly correlated throughout the day for the male and the receptive female, and they often marked in the same locations. The male marked more frequently when the receptive female was active and the female's marking was often associated with behavioural interactions. These findings suggest a major female influence on male marking and activity and suggest that marking may facilitate social interaction. In the spring following this study, the receptive female successfully whelped a litter, the first to be conceived and born in this captive breeding program. The results of this study may help establish successful protocols for captive breeding programs, and thus aid efforts to conserve this endangered species.

Résumé : Nous avons étudié les modifications du comportement associées à la reproduction chez des Martres de Terre-Neuve (*Martes americana atrata*), une espèce menacée. Le marquage d'odeurs et les interactions comportementales ont été enregistrés avant et après l'introduction d'un mâle auprès de deux femelles . En présence du mâle, le marquage a augmenté chez la femelle réceptive, mais a diminué chez la femelle non réceptive qui est devenue moins active. L'activité et les périodes de marquage étaient en corrélation significative toute la journée chez le mâle et la femelle réceptive et les deux faisaient souvent leur marquage aux mêmes endroits. Le marquage du mâle était plus fréquent lorsque la femelle réceptive était active et le marquage de la femelle était souvent associé à des interactions comportementales. Ces résultats reflètent l'influence importante des femelles sur le marquage et l'activité des mâles et indiquent que le marquage facilite probablement les interactions sociales. Au printemps qui a suivi cette étude une femelle réceptive a mis bas avec succès, la première portée conçue et née au sein de cet élevage en captivité. Ces résultats pourront être utilisés pour établir des protocoles dans des programmes, souvent ratés, d'élevage en captivité et, par le fait même, contribueront aux efforts de conservation de cette espèce menacée.

[Traduit par la Rédaction]

Introduction

The Newfoundland marten (*Martes americana atrata*) is an endangered subspecies of the American marten (*Martes americana*). Populations have declined significantly since the 1800s, most likely as a result of habitat loss by logging and overtrapping, which has restricted the majority of remaining individuals to a small area in western Newfoundland. A captive breeding project was established at Salmonier Nature Park, Newfoundland, in 1995 as part of the National Recovery Plan for the Newfoundland Marten. Although general information on the breeding cycle of the mainland subspecies, *Martes americana americana*, is available, most attempts to breed martens in captivity have either failed or produced inconsistent results (Pitcher 1996).

The breeding season for martens starts near the beginning of July and may last until the end of July (Grant and Hawley 1996) or August (Mead 1994). As this season approaches, both captive and wild martens show increases in scent-marking, intersexual body contact, and intrasexual female aggression (De Monte and Roeder 1990; Helldin and Lindström 1995; Grant and Hawley 1996). Scent-marking by the closely related stone marten, *Martes foina*, also increases (Lodé 1991; Seiler et al. 1994). Martens have anal and abdominal scent glands and mark by dragging their abdomen over the ground and trees or by spraying (*Martes martes*,

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Ewer 1973; De Monte and Roeder 1993). Ewer (1973) suggested that marking may facilitate the meeting of otherwise solitary individuals in the wild; however, information on the function of marking during the breeding season is limited.

The mating behaviour of American martens is reported to be the same as for *Martes* species in general. Mating is often interspersed with mock wrestling. Female martens appear to control the actual timing and duration of mating, and even encourage the male on some occasions (Grant and Hawley 1996). Mounting durations for martens range from a few minutes to more than an hour (Siefke 1960; Henry and Raphael 1989; Lodé 1991; Ruggiero and Henry 1993; Mead 1994). Multiple copulations have been observed over several days (Markley and Bassett 1942), and may be required for ovulation and subsequent conception in mustelids (Mead 1994). Apart from this general knowledge, detailed information on courtship behaviour is lacking in the literature.

The present study reports changes in activity and behaviour of two captive female Newfoundland martens before and after the introduction of a mature male. Accurate description and quantification of martens' behaviour associated with reproduction may be invaluable for establishing breeding protocols and monitoring techniques to be used in captive breeding programs.

Materials and methods

Prior to this study, one female (hereinafter female 1) and one male marten (*M. a. atrata*) were livetrapped in late September 1995 in the Red Indian Lake area of western Newfoundland. The other female (hereinafter female 2) was captive-born to a female not associated with this study in April 1996. At the beginning of this study, females 1 and 2 were held individually in two adjacent wire-mesh enclosures (each 3.05 × 5.2 × 4.4 m) with exterior and adjoining doors. Each enclosure contained a plywood nest box (internal dimensions 0.30 × 0.30 × 0.48 m), a feeding shelter, and an assortment of live and dead trees to enrich the environment. Enclosures were located in a mature coniferous forest, allowing a natural photoperiod and weather conditions.

Each enclosure was equipped with one Sony SPTM104A camera with a wide-angle auto-iris lens and a built-in infrared light source. Detailed behavioural observations were not possible during the night, but preliminary observations indicated that nocturnal activity was minimal. A Gyyr DQ88 Dual quad mixer allowed images to be recorded from the two cameras simultaneously onto one tape. Video was recorded in time lapse (12 h per 2-h tape) by a Toshiba KV7024A VCR. Videotapes were then analyzed using a Sony SLV-696HF 4-head VCR with slow play and frame-by-frame control.

Video recording began on May 15, 1998. The male was introduced to female 1 on June 30, 1998. The male was then given access to female 2 on July 11, 1998, by opening a door between the two females' cages. Individuals could be identified on videotape from differences in fur coloration and by tracking individuals. The male was removed and the females were separated on September 9, 1998.

Four videotapes were analyzed before (June 9, 14, 18, and 20, 1998) and four after (July 12, 23, and 27 and August 6, 1998) the male was introduced, for a total of 96 h for each female (48 h for the male). We recorded and described the frequency of abdominal scent- and spray-marking, time spent active, frequency of male–female interactions (i.e., courtship and general body contact, including chasing and mock wrestling), and frequency of mounting behaviour, which was also included in calculations of interaction time. These behaviours were recorded from videotapes by reporting all occurrences of each behaviour (Altmann 1974). Durations of mating, male–female interaction bouts, and periods of inactivity (when animals were not seen to be moving for more than 5 min) were determined and used to calculate the amount of time spent active, the amount of time both animals spent active, and the amount of time spent interacting. The frequency of each behaviour was then calculated per day and for each hour of the day (09:00–20:59) and data were analyzed using Pearson's correlation and analysis of variance.

Results

Qualitative behaviour

Following the introduction of the male and the opening of the adjoining females' cages, observations indicated that female 1 began to use both enclosures and often interacted with the male. Female 2, however, avoided the other individuals, spending most of the time inside her nest box. On several occasions the male and female 1 were seen to make alternate marks several times in sequence at the same location within a brief period of time (1–5 min). On two occasions female 1 marked directly on the male and on one occasion the male marked directly on female 1.

Brief chases were often seen and sometimes led to a wrestling bout. Chasing was initiated by either the male, the female, or both. The male initiated 9 and female 1 initiated 13 of 22 interaction bouts in which the initiator could be determined (approximately 25% of all interaction bouts). These interactions did not seem to be aggressive, and neither individual seemed to dominate wrestling bouts on all occasions.

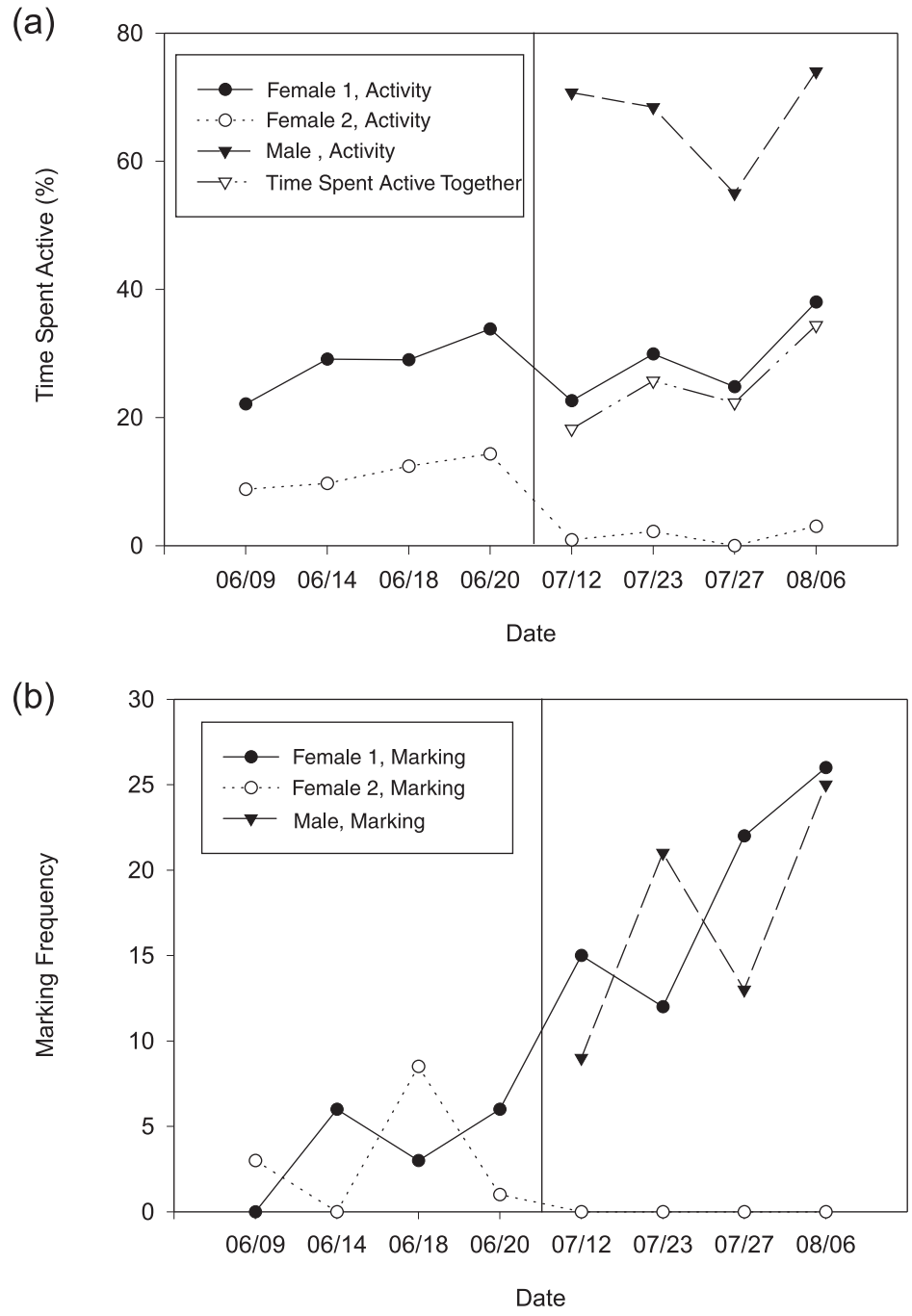
Mounting bouts were observed 17 times during observations. Thirteen of these mounting bouts were observed on July 12 and 23, just after introduction of the male. Mounting bouts were not significantly correlated with marking or any other activity. Apparent intromission occurred several times during mounting; however, the range of mount durations was only 4–49 s (mean duration 12 s). This female subsequently produced a litter of three kits, the first successful conception and birth for the Newfoundland subspecies' captive breeding program. Further behavioural details are reported by Heath (1999).[2]

Behavioural differences before and after introduction of the male

Although female 1 showed no significant change in the amount of overall activity (Fig. 1*a*), she marked significantly more ($F_{[1,6]} = 13.33$, $p = 0.01$) after the male was introduced (22.5 ± 8.06 times per day) than before (6.0 ± 4.08 times per day; Fig. 1*b*). Female 2, on the other hand, decreased activity from before (11.3 ± 2.52%) to after male introduction (1.53 ± 1.34%; $F_{[1,6]} = 47.05$, $p < 0.001$; Fig 1*a*) and ceased marking (Fig. 1*b*).

[2] J.P. Heath. 1999. Reproductive behaviour changes and non-invasive hormone extraction in the endangered Newfoundland pine marten (*Martes americana atrata*) in captivity. B.Sc.(Hons.) thesis, Memorial University of Newfoundland, St. John's.

Fig. 1. (*a*) Daily activity before and after introduction of the male. Female 2 became less active after the male was introduced, whereas female 1's activity did not change. Female 1's activity was significantly correlated with the amount of time that both were active at the same time. (*b*) Frequency of marking before and after introduction of the male. Female 1 marked significantly more per day after the male was introduced (mean = 22.5) than before (mean = 6). Female 2 ceased marking after the male was introduced. The vertical line represents the introduction of the male. Dates are given as month/day.



Behavioural synchrony among individuals

The male was significantly more active than female 1 ($F_{[1,11]}$ = 48.19, $p < 0.001$) on a per-hour basis. Female 1's activity per day was highly correlated with the amount of time that the two animals were simultaneously active (r = 0.992, df = 2, p = 0.01; Fig. 1*a*), indicating that the male was almost always active when female 1 was. The activity patterns of both female 1 (r = 0.7443, df = 10, $p < 0.01$) and the male (r = 0.7815, df = 10, $p < 0.01$) were correlated with the frequency of interaction patterns, as would be expected.

Female 1's marking frequency was significantly correlated with how often the pair interacted (r = 0.6829, df = 10, $p < 0.05$), whereas the male's marking was not (r = 0.3295, ns; Table 1, Fig. 2). Female 1's marking was significantly correlated with the male's activity (r = 0.5946, df = 10, p = 0.05) and marking patterns (r = 0.6359, df = 10, p = 0.05; Fig. 2).

Fig. 2. Within-day interaction and marking patterns during the days that the male was present. Female 1's marking frequency was significantly correlated with the amount of interaction, whereas the male's marking was not. The male's marking was significantly correlated with the females' marking patterns (see Table 1).

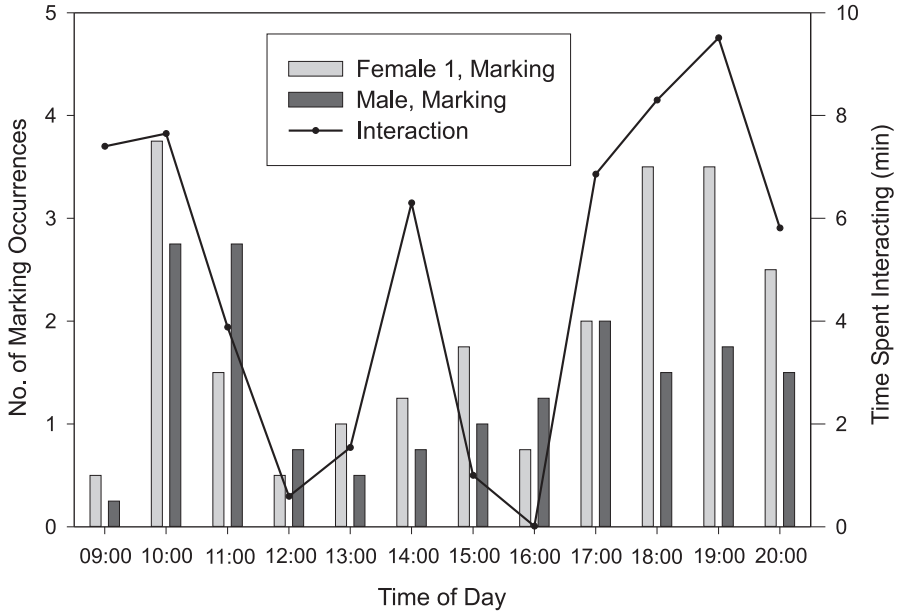


Table 1. Correlation coefficients for patterns of activity, marking, and interactions by the male and female 1 during the days after the male was introduced.

	Male		Female 1	
	Activity	Marking	Activity	Marking
Male's marking	0.621*			
Female 1				
Activity	0.677*	0.592*		
Marking	0.595*	0.636*	0.572	
Interaction frequency	0.782**	0.33	0.744**	0.683*

Note: Frequencies of each behaviour were calculated for each hour (09:00–20:59) and averaged for the 4 observation days when the male was present.

*$p < 0.05$.

**$p < 0.01$.

The male and female 1 preferred the same marking locations ($r = 0.935$, df = 10, $p = 0.01$). No difference was found in total marking frequency or in the frequency with which each marked a particular site.

Discussion

In various mustelid species the frequency of scent-marking increases as the breeding season approaches (ferret (*Mustela furo*), Clapperton 1989; *M. americana*, DeMonte and Roeder 1990; *M. foina*, Lodé 1991; Helldin and Lindstrom 1995; Grant and Hawley 1996; Seiler et al. 1994). In this case, however, large differences in marking frequency were observed immediately after the male was introduced, indicating that this change in behaviour may be mediated, in part, by interaction with a conspecific, as opposed to just being a response to seasonal cues. Female 2 was seldom active and ceased marking after the male was introduced. As this female became inactive less than 1 min after the other individuals became active, it appears that she intentionally avoided social interactions. This may have been due to her life in captivity and (or) her status as a subordinate.

Our results suggest that females control the timing of males' marking and pair interactions. First, the male was almost always active during the females' activity bouts and marked more during this time. Second, female 1's marking bouts were usually interspersed with pair interactions, whereas the male's marking bouts were not. Females have been reported to control the frequency and duration of mating (Grant and Hawley 1996); however, our results also suggest female control of the direct and indirect interactions that precede mating.

De Monte and Roeder (1993) found that in male–female pairs, one individual's marking frequency may be influenced by that of the other individual. The male and female 1 tended to mark similar amounts in the same locations. Qualitative observations also revealed that after one individual had marked in a particular location, the other would often sniff this area and mark over or next to it before leaving. Several possible functions of marking are suggested by these observations. First, in wild situations, males' markings may serve as an indicator to other males that the female is already attended, thereby playing a dual role in territory and mate defence. Females' markings, however, probably indicate receptivity and attract males, as they increase in frequency during the breeding season, a suggestion supported by the findings that ferrets recognize individuals by their markings and that males prefer females' markings (Clapperton et al. 1988). Second, females' marking may serve to communicate increasing receptivity to the courting male and possibly even indicate when mating would result in ovulation. Finally, these indirect interactions by marking may serve to generate excitement, leading to chasing, wrestling, and eventually mating. This hypothesized function of marking was supported by a within-day correlation between female marking and pair interaction time.

Grant and Hawley (1996) noted that pairs of female martens differed in how aggressive they were, and that successful breeding by one individual in the pair only occurred when the two were so aggressive that they had to be separated. Thus, it is not certain whether the clear dominance difference (similar to the present study) or the separation of the two resulted in successful breeding. Separation or clear subordination may be important for martens, as the home ranges of females in free-ranging populations do not overlap (Powell 1994). The extreme lack of activity by the subordinate female in this study may have produced, in effect, a situation in which breeding was not affected by her presence. The successful parturition following this study, in addition to Grant and Hawley's (1996) results, suggests that single female–male pairings may be a better approach to use in captive breeding programs than introducing a male to multiple females.

In martens, breeding involves a long series of complex behavioural interactions. Indirect interactions, such as scent- and spray-marking, likely serve to bring individuals together for more direct interactions such as chasing and mock wrestling, eventually leading to mating sequences. Many of these sequences appear to be controlled by the female. Future research should combine behavioural observations with techniques for monitoring endocrine hormones in order to more precisely determine the functions and mechanisms of these reproductive-behaviour strategies.

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