Natal den activity patterns of female pine martens (*Martes martes*) in the Netherlands

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Abstract: Maternal pine marten (*Martes martes*) den activity patterns at sixteen natal dens with kittens were studied in three separated forests in the north of the Netherlands from 1998–2007, using temperature recordings inside the den. All dens were old tree cavities of the black (*Dryocopus martius*) and the green woodpecker (*Picus viridis*). Temperature data indicated specific moments of arrival and departure of the female. Litter sizes varied from one to four kittens. Occupation of the dens ranged from 45 to 70 days and seemed to be affected by litter size. Attendance data were analysed on a daily basis and compared between two time intervals defined as pre-weaning and weaning periods. The proportion of time females spent at the den decreased (P<0.0001) from the pre-weaning to the weaning period. The average time spent at dens varied from 9.1 to 13.8 hours whereas the average time spent away from dens varied from 5.3 to 6.1 hours. Attendance was affected by the age of the kittens and time of the day. Long away events did not start until the second week of kitten age. Den attendances appeared to be mainly diurnal and time spent at dens decreased as kittens grew older. Time spent away at dens (mostly nocturnal) increased due to an earlier departure while moments of arrival continued to be constant and were related to sunrise. Long away events were followed up by long home events and short away events by short home events. During the period of weaning the activity bouts, home as well as away, were no longer related to day or night.

Keywords: Martes martes, pine marten, natal den, maternal den, den attendance, den use, activity.

Introduction

Information about patterns of natal den attendance of female pine martens (*Martes martes*) is important for our understanding of habitat needs for successful recruitment. Little is known about the behaviour of female pine martens from parturition to independence of the kittens in a natural habitat. Existing literature is mostly restricted to observations of martens living in captivity (Schmidt 1943, Herter & Ohm-Kettner 1954, Goethe 1964, Herrmann & Knapp 1984, Jokish 1992, Seidl 1993). Scant studies refer to aspects of female activity during development of the kittens in a natural environment but they did not all include the early natal period (Broekhuizen & Müskens 1997, Henri et al. 1997, Müskens 1997, Kleef 2000).

Den site activity patterns of the female pine marten may be affected by several environmental factors such as dispositions of the natal den, weather conditions, night and day, prey availability and prey activity rhythm (Zielinski et al. 1983, Broekhuizen & Müskens 1997, Zielinski 2000). However, when nursing, the female behaviour may be foremost determined by factors related to litter care such as litter size, the age of the kittens, and the energetic requirements of either both female and kittens, rather than environmental factors.

The objectives of this study are to quantify den activity patterns of female pine martens throughout the denning period and to examine whether this activity could be related to kitten development, time of the day, and litter size.

Material and methods

Study areas

The study was conducted at three areas located in the north of the Netherlands (figure 1): the National Park of Drents-Friese Wold (DFW; 6000 ha) and the forests of Veenhuizen (VH; 650 ha) and Borger (BO; 2400 ha), the latter at distances of respectively 15 km northeast and 30 km east of the National Park, from which they are separated by a flat peat moor nature reserve and cultivated land. These three forested areas are nature reserves where the nature management is directed to the preservation and strengthening of nature values but also gives way to recreational objectives. Possession and management is done by the State Forestry Service (Staatsbosbeheer) and the Society for the Preservation of Nature in the Netherlands (Society Natuurmonumenten).

The forests are about 60 years old, and mostly coniferous (DFW 75%, VH 55% and BO 66%). The coniferous sections are predominated by Scotch pine (*Pinus sylvestris*), spruce (*Picea alba*), douglas fir (*Pseudotsuga menziesii*) and larch (*Larix kaempferi*) followed by a mixture of fir, i.e. silver fir

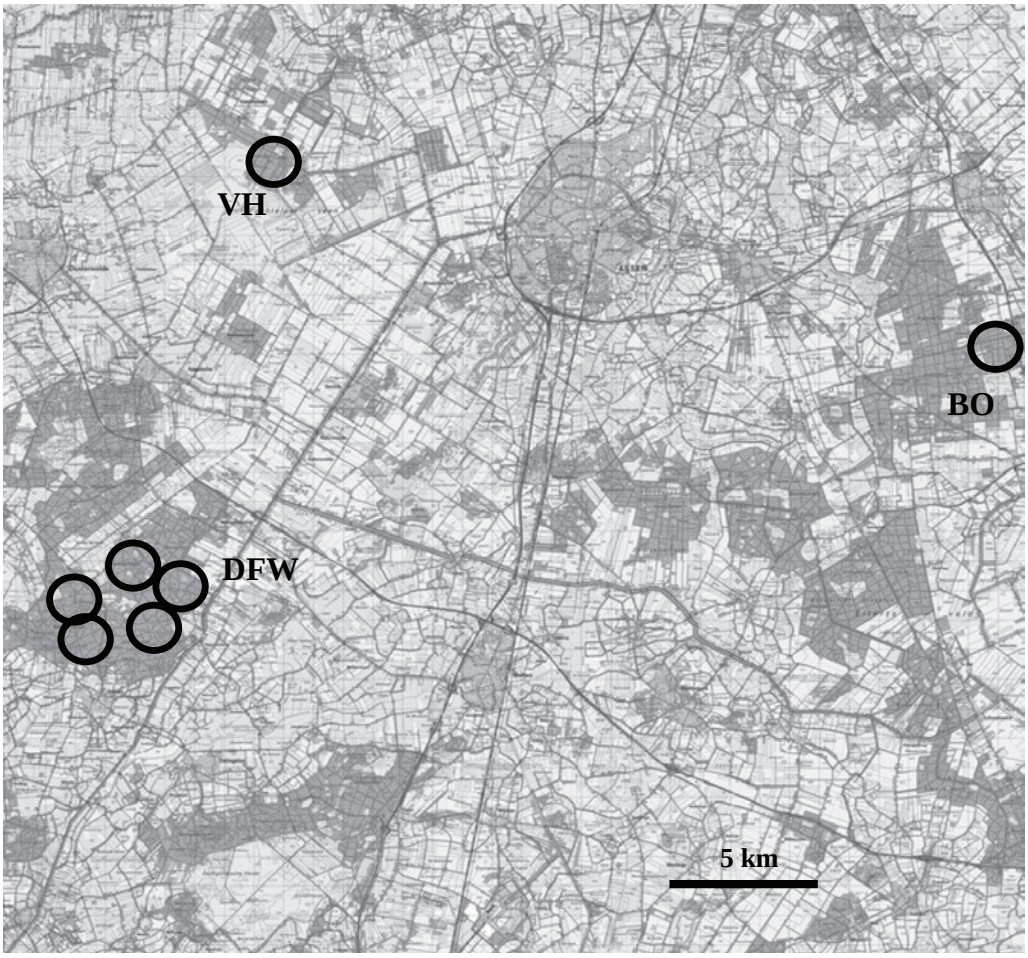

Figure 1. Study areas with female pine marten denning sites in the National Park Drents-Friese Wold (DFW) and the forests of Veenhuizen (VH) and of Borger (BO).

(*Abies alba*), sitka spruce (*Picea sitchensis*), black pine (*Pinus nigra nigra*) . The deciduous parts are mostly beech (*Fagus sylvaticus*), oak (*Quercus* spec.) and birch (*Betula* spec.) (DFW 9%, VH 24% and BO 14%). Roads, clearcuts, belts and a few meadows cover the remainder of these areas.

Dens

All den sites involved in this study were old tree cavities of the black woodpecker (*Dryocopus martius*) and the green woodpecker (*Picus viridis*). The dens were situated in larch (5x), beech (5x), Scots pine (4x) and oak (2x) at heights varying from three to twelve meters. The diameter of the den cavities measured at the lowermost entrance level varied from 18 cm to 28 cm (average 23 cm) and depths ranged from 10 cm to 33 cm (average 22 cm) measured below the lowermost entrance. Nine cavities had a single entrance only. At the remaining seven cavities the number of entrances varied from two to four. Most of the entrances were exposed to the NE, a few to the SE or SW. It could not definitely be proved that the same individual female occupied repeatedly used dens.

Temperature registration

Den attendance of the female pine marten was determined by temperature changes inside the den. The temperature was recorded using programmable data loggers, type Tinytag IP 68 (INTAB Benelux, Cuijk), connected by a cable to an external temperature sensor (see for technical details Kleef 2000). Temperature changes could accurately be related to the females' time of arrival at and departure from the den. Field observations matched these transitions. Information about installing the sensor inside the den, programming the data loggers and the course of the temperature recorded is provided in detail in Kleef (2000). The temperature sensors were placed at prospective den cavities, which were selected from denning observations in preceding years (Kleef 1998). Parturition dates could be accurately established from temperature readings because of long and nearly uninterrupted stay of the female inside the den. Sometimes, however, the female decided to choose an unexpected den site. The sensor then was placed mostly within one week after she gave birth during absence of the female. Parturition dates then were estimated from kitten habitus by inspecting the litter by eye or IR camera inside the den but might differ from actual date of parturition for several days. Temperature recordings were downloaded on a weekly basis.

Data analyses were based on a daily age of the kittens at two major age classes: pre-weaning (<6 weeks old) and weaning (≥6 weeks old). The times of the females' arrivals and departures were rounded off to the nearest quarter of an hour, presented in Mean European Time. Defecation and urination at the latrine directly outside the den, very brief prey deliveries and exploration through one of the entrances by the female may cause short time changes of temperature inside the den. For that reason all events lasting less than 30 minutes were omitted from the analysis.

To compare percentages of time spent at dens between weaning and pre-weaning periods a two-tailed paired *t*-test was used (Henri et al. 1997). Because data were not normally distributed nonparametric tests, such as Kolmogorov-Smirnov and Kruskal-Wallis, were used to compare the length of events in pre-weaning and weaning periods and to compare the periods of den attendance with various excursions.

Results

Parturition occurred from late March to half of April. Temperature readings were obtained up to the ninth week of kitten age after which the readings were no longer of value due to the

Table 1. Percentage of time spent at natal dens by female pine martens at three different study areas and 16 dens in the Netherlands. Also included in the table litter size ('kittens') and occupation time ('days') from parturition to relocation (? = unknown litter size).

					Pre-weaning		Weaning	
Area	Den	Year	Kittens	Days	Hours	%	Hours	%
DFW	3	1999	3	52	327	70	212	66
DFW	3	2000	1	60	743	80	371	71
DFW	3	2001	4	50	579	76	154	68
DFW	3	2002	?	54	620	78	310	68
DFW	3	2006	3	52	521	64	156	47
DFW	1	1998	3	56	641	73	192	61
DFW	1	1999	4	45	436	80	115	76
DFW	4	2001	3	51	500	76	184	60
DFW	4	2003	3	52	634	70	133	59
DFW	6	2005	3	64	462	70	307	54
DFW	7	2007	?	52	652	74	200	61
VH	2	1998	3	53	270	63	147	50
VH	2	2000	3	58	487	68	148	42
VH	2	2001	3	58	355	71	218	57
BO	5	2005	2	75	661	73	195	53
BO	5	2007	2	60	583	70	121	71

growing kittens and / or the relocation of the litter to a new den.

A total of 17,001 hours of den attendance data were obtained at seven different sites and 16 litters distributed over nine years. In all of the 16 litters martens spent a major proportion (>62%) of their time inside the maternal den (range: 63%-80%) during pre-weaning. During weaning in only six litters the same proportion of time (>62%) was spent inside the den (range within all litters: 42%-76%; table 1). The reduction of time spent inside the den between pre-weaning and weaning proved to be significant (paired *t*-test: $P<0.0001$).

The average (x ± se) time spent inside the den during the pre-weaning period (13.8 ± 0.26 hours, $n=613$) was significantly ($P<0.0001$) longer compared to the period of weaning (9.1 ± 0.31 hours, $n=348$). The average time spent outside the den was significantly ($P=0.0035$) shorter during the pre-weaning period (5.3 ± 0.13 hours, $n=606$) than during the weaning period (6.1 ± 0.20 hours, $n=353$). During pre-weaning as well as during weaning duration of inside events was longer than outside events ($P<0.0001$).

Kittens were more frequently attended for longer periods during pre-weaning and were more frequently left alone for short periods during weaning (figure 2). Figure 2 appeared to be clearly bimodal, showing peaks of short time and long time home events throughout the denning period. The threshold at which these different home events could be separated was estimated at eight hours resulting in two specific home events: short (average four hours) and long (average 16 hours). After parturition when kittens were less than a week old, away events did not show any bimodality. The average duration of these events was two hours in this stage. After the first week bimodality of away events appeared to be clear throughout the remainder of the denning period and as a result could be separated at a threshold of five hours resulting in two specific away events: short (average three hours) and long (average eight hours). The long events, home as well as away, are affected by kitten development

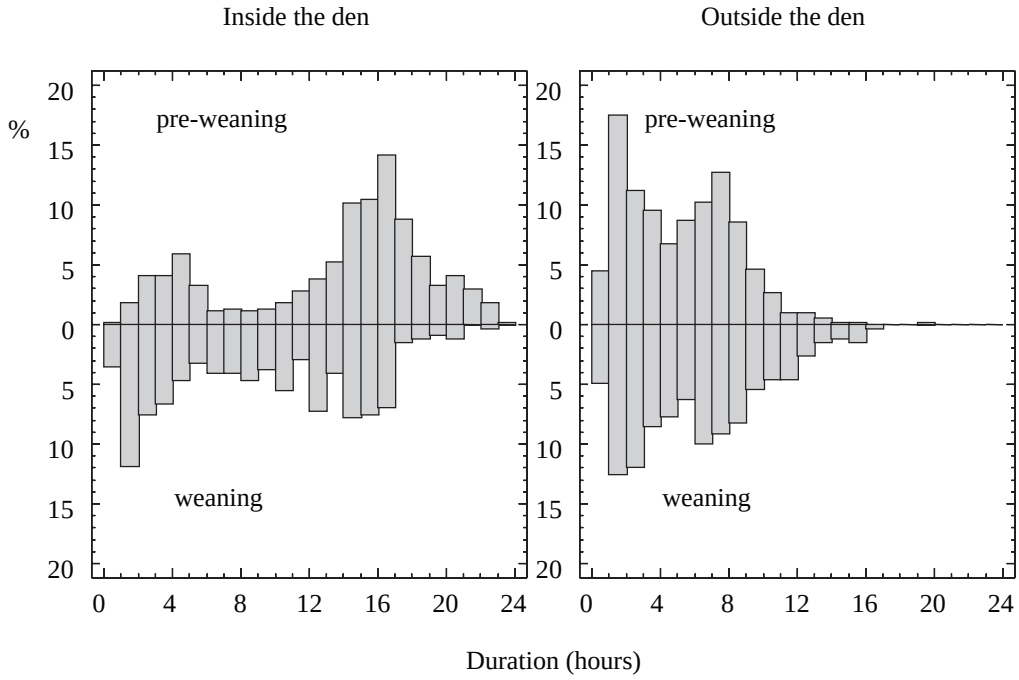

Figure 2. Relative frequency distributions by duration of events (hours) at two age classes of kittens.

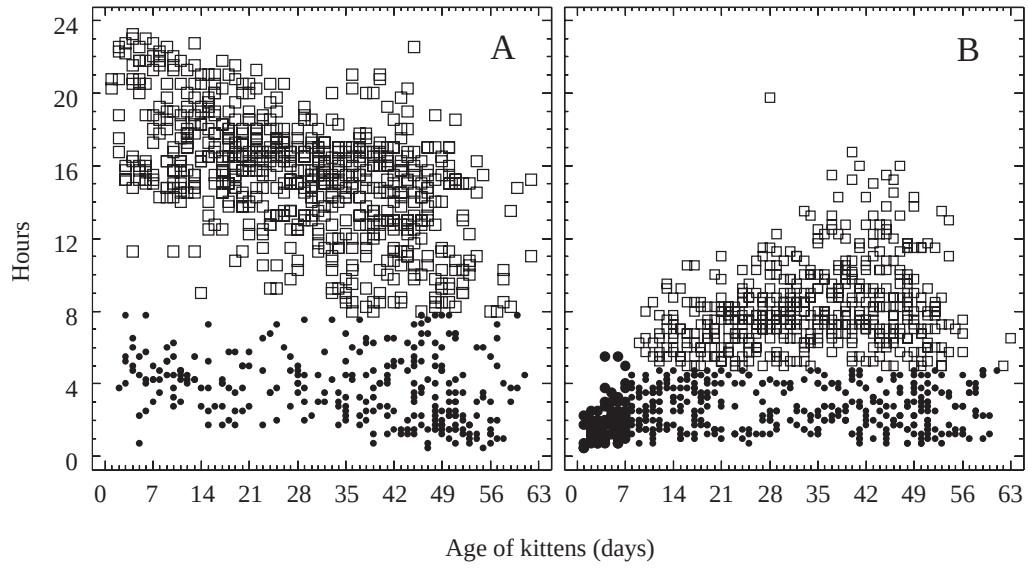

Figure 3. Arrangement of five groups of denning events (daily average duration in hours) of long (≥8 hours) and short (<8 hours) home events (A) and of long (≥5 hours) and short (<5 hours) away events (B) related to the age of the kittens (squares: long events; dots: short events; see also text).

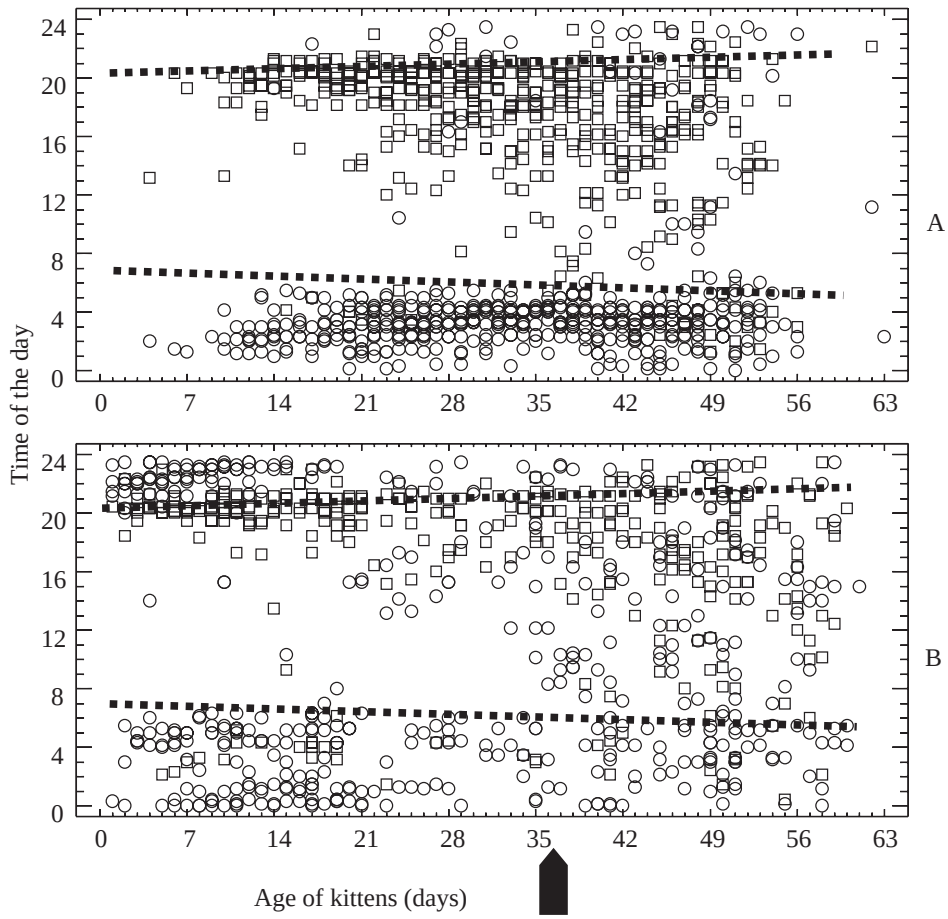

Figure 4. Times of den arrival (circles) and den departure (squares) of long (≥5 hours) away events (A) and short (<5 hours) away events (B) of female pine martens related to kitten age; (dotted lines approximately indicate sunset respectively sunrise; the arrow indicates the beginning of weaning).

as can be seen in figure 3, showing how the events are arranged throughout the denning period on a daily basis. The duration of long home events decreased steadily throughout the whole denning period while the duration of short home events also show a decreasing tendency (figure 3A). The long away events increased while the short away events appeared to be independent of kitten development (figure 3B).

Departures and arrivals ranged from one to six times a day and were affected by kitten development and night and day (figure 4). During the years involved in this study the times of sunset and sunrise moved from about 8.15 pm respectively 7 am early in April to 9.45 pm respectively 5.15 am at the end of May. Long events did not begin until the second week of kitten age. The times of departure for long away events were mainly grouped round sunset at 8 to 9 pm especially in the second and third week. They gradually shifted to the middle of the day when kittens grew older. Nearly all of the long away events ended between midnight and 5 am (before sunrise) independent of kitten age and therefore happened to be mainly nocturnal (figure 4A). Short away events were mainly limited to the hours of the

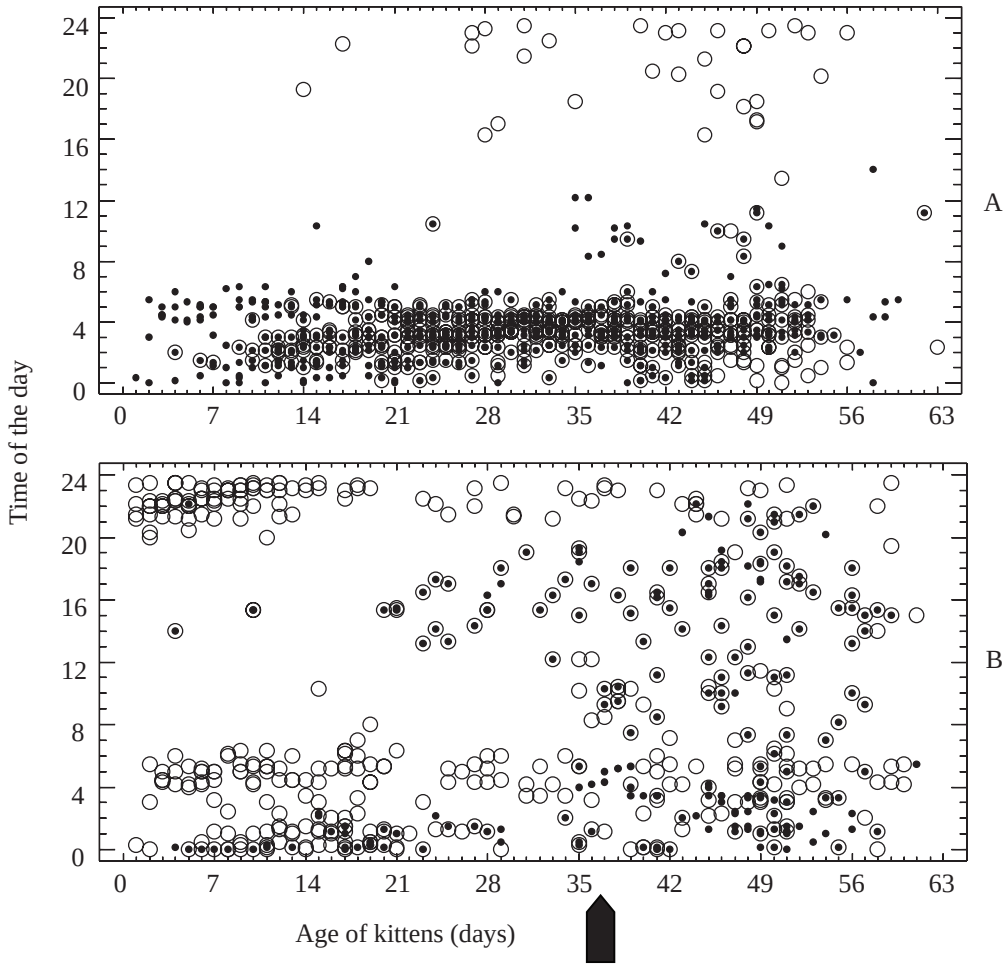

Figure 5. Den arrivals of female pine martens. The end of away events (circles) and beginning of home events (dots). Overlay of both moments indicate that an away event is followed by a home event. A: long away (≥5 hours) and long home (≥8 hours) events. B: short away (<5 hours) and short home (<8 hours) events (the arrow indicates the beginning of weaning).

night, especially during the first three weeks of kitten age. From that time on the short away events shifted more and more from nocturnal to diurnal at which any relation to dark or light seemed to be lost (figure 4B).

In order to establish whether long away events were followed by long home events and short away events were followed by short home events, the moments of arrival of both events were placed in one plot (figure 5). When both moments of arrival overlay, the events are coupled i.e., a specific (long or short) away event is followed up by a specific (long or short) home event. It is apparent that most of the long away events were followed up by long home events (figure 5A) and that short away events were followed up by short home events, the latter more often during daytime (figure 5B).

Litter sizes varied from one to four kittens (table 1). The small sample size of 14 litters with known size (1 x 1, 2 x 2, 9 x 3 and 2 x 4 kittens) suggests that statistically testing the

effect of litter size on den attendance would be unmeaning. However, the increase of the average proportion of time spent outside the den from 24% to 35% at litter sizes from one to three, and the drop down to 24% at litter sizes of four, might indicate an affect of the female's time spent outside the den probably to fulfil energy demands of her own and of her kittens.

As can be seen in table 1, both litters of four kittens were relocated after 45 and 50 days after birth, eight out of nine litters of three kittens between 51 and 58 days and the three litters of one and two kittens after 60 to 75 days, indicating that litter size might affect the moment of relocation.

Because the combined data about the duration of time spent inside and outside the den were not normally distributed, a natural logarithmic transformation was performed resulting the data to be close to normality. By calculating the natural logarithm of the ratio of average duration of the time spent inside and outside the den for each of the three study areas from week number two to week number seven - the period of weekly prolonged times spent away from the den - the activity pattern shown in figure 3 can be transformed to a significant negative linear regression with the age of the kittens (P=0.0001, R^2 = 86.6%). The intercept of the three regression lines differs significantly (P=0.0251) while slopes are assumed to be equal (P=0.2352), showing a significantly different behaviour of the females in study area VH (P=0.0281) compared to the females in areas DFW and BO with similar behaviour: P=0.8293 (figure 6). This is consistent with a higher proportion of time spent away from the den at study area VH (39%) compared to the study areas DFW (30%) and BO (31%) with nearly equal proportions.

In 2005 and in 2006 the average duration of outside events seemed to be distinctly shorter (4.5 hours ± 0.2, n=192) respectivily longer (8.2 hours ± 0.5, n=57) than in all others years (5.6 hours ± 0.3, n=710). Because of the small number of females per year no attempt was made to statistically analyse these events among years.

Discussion and conclusions

Temperature measurements and den use

The present study indicates that temperature logging inside a natal den is an adequate tool to collect data about patterns of natal den attendance of the female pine marten and also provides accurate dates of parturition and dates of relocation. From temperature measurements throughout the year it has been established (Kleef, unpublished results) that some of the females occupied a den from January onward but yet switched to a nearby den shortly before parturition. However most of the pregnant females seemed to occupy their natal den the night preceding parturition. On a few occasions females relocated their litter already in the first week after they had given birth but usually the occupation of the natal den lasted as long as seven to nine weeks. This is in accordance with relocation data of Wynne and Sherburne (1984), Jokish (1992), Henri and Ruggiero (1994), Müskens (1997) and Kleef (2000). As a rule at the age of seven to eight weeks kittens are not yet able to climb (Kleef, unpublished results). It is not known why the female relocates her litter to another den, often before the kittens were able to climb. It is assumed that predation risks, contamination of the den by parasitic, faecal or prey remnants play a role (Goethe 1964). However, after inspecting several natal dens shortly after desertion they appeared to be clean and were lacking visible parasitic presence as was found with fishers (*Martes pennanti*) (Powell 1993). Maybe litter size itself may play a role in the decision to relocate because litter size seems to be related negative to the number of days the dens were occupied. This may indicate that litter size determines the moment of lack of room for female and kittens in the natal den, especially regarding the vivaciously activity of young

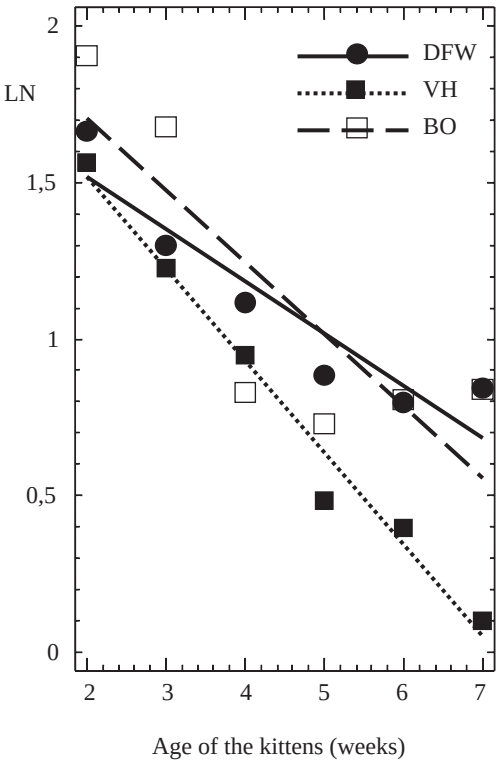

Figure 6. Regression of natal den attendance events by area (DFW, VH, BO) related to kitten development. LN: natural logarithm of the ratio between time spent inside and time spent outside the den (explanation in the text).

martens at about that age and taking into account that diameters of natal dens have been found to be as small as 16 cm (Broekhuizen & Müskens 1997, Kleef, unpublished results). In this study three den cavities had a diameter of only 18 cm in which litters of three and four kittens had been found. These dens were relocated after 50, 51 and 52 days, the three shortest periods of occupation except the one of 45 days with a litter size of four and a diameter of 26 cm. So grown up kittens, especially from litters of three or more kittens may cause to lack of room and as a consequence forces the female to relocate her litter, taking in account the dimensions of the cavity.

Monitoring of the temperature inside tree cavities may also yield valuable data about seasonal use of tree cavities from which martens denning behaviour – pine martens as well as beech martens (*Martes foina*) – might be explained. Year-round temperature monitoring in tree cavities that have never been used as a natal den only revealed short visits which varied in length from less than a single hour to a few consecutive days, mostly in autumn and winter. By contrast, such visits have hardly been seen when cavities known as natal dens were similarly monitored throughout the year but this might be explained by the randomly distributed use of resting sites (Zalewski 1997). However, Brainerd et al. (1995) established the same phenomenon suggesting different salient features of resting sites and denning sites. A substantial number of unpublished measurements of cavity characteristics such as internal dimensions of the cavity, number and exposition of entrances or height of the cavity indicate that these morphological features will probably not contribute to an understanding of why the female chooses a specific cavity as a natal den.

Female activity

The variation of den attendance patterns found in this study seems to be clearly influenced by the degree of kitten development and night and day, which was in accordance with patterns of den attendance of female American martens (*Martes americana*) (Henri et al. 1997). In their first days the neonates strongly depend on female care. The skin of the ears, the tail and the inside of the extremities are nearly bare, as is with beech martens (Schmidt 1943, Ludwig 1998). This poor isolation at still chilly temperatures forces the female to stay with her kittens for prolonged periods of time. Especially immediately following parturition females attended their new borns for up to 66 hours with only very short excursions to defecate and urinate. Because of this pressure of kitten care the female avoided long hunting trips during the first week of kitten age and spent no more than a few nocturnal

hours away from the den as a need to meet her energy demands possibly to recover from given birth. This pattern was also observed by Ludwig (1992) and by Powell (1993) for fishers. Not only energy demands, but also synchronisation with prey activity patterns may explain the duration and moment of hunting trips. Pine martens prey principally on rodents, like the bank vole (*Myodes glareolus*) and the wood mouse (*Apodemus* spec.), of which peak activities in spring coincide with the nocturnal short trips maintained throughout the denning period independent of kitten age (Wójcik & Wolk 1985, Clevenger 1994, Zielinski 2000). These short nocturnal trips might be used to feed herself outside the den after having caught small prey. During weaning also diurnal short hunting trips were carried out possibly as a result of increasing availability of bird eggs and bird nestlings as easy prey items to feed her offspring. More than once was observed that after delivery of prey the female stayed in the den while kittens competed violently for the food items, followed up by a deep rest for a number of hours.

After the first week of kitten age the females started to carry out longer trips, which more and more extended under the increasing pressure to hunt in order to meet the energetic demands of lactation and of feeding their kittens with solid prey after weaning has been started (Schmidt 1943, Herter 1953, Ludwig 1992, Powell 1993, Seidl 1993, Mead 1994, Müskens 1997, Zielinski 2000). The more the hunting trips extended the more the time to rest and nurse their young inside the den diminished, which might affects these needs. However not all of the time spent away from the den is necessarily needed for hunting activity but also may be used for territorial defending actions and for resting as was observed by Henri et al. (1997). After the start of the weaning period nearly all night and day related activity disappeared, which was also found with fishers (Paragi et al. 1994).

Observations with small IR cameras inside the den showed that females when present were most of the time sleeping or resting while nursing. Short activity bouts, both of kittens and female, often occurred immediately after arrival of the female whether or not prey had been delivered, and came about again shortly before she departed.

Natal den activity of the female pine marten might be affected by local or temporal differences of prey availability. In this study the proportion of the females' time spent outside the natal den in study area VH seems to be longer when compared with study areas DFW and BO as a result of significantly prolonged hunting bouts in area VH, constantly throughout the period of kitten development from week two to week seven. This local difference gathered from the combined data was also found on an individual level after comparing denning activity of two females in the same study areas (Kleef 2000). Neither habitat type and habitat structure nor litter size is likely to explain this different behaviour. It might be supposed that in the smallest study area VH the food conditions suffice just to survive and reproduce and therefore forces the female into increased activity by extending her hunting bouts (Zielinski 2000). However the data from area VH in the years involved probably originated from one and the same female and therefore this difference might also be assigned to the female's intrinsic behaviour. Not only local differences but also year to year variation of prey availability may affect the female's hunting duration. In 2006 the average time spent away from the den was almost twice as long as in 2005, which correlates with the bad and good food conditions regarding the availibility of the wood mouse in the corresponding years (Bijlsma 2009).

It seems to be clear that the activity pattern of the female pine marten during nursing is strongly related to kitten development and night and day. However an understanding of the environmental factors that affect this relationship will require more field studies directed toward factors regulating successful reproduction of the pine marten.

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Samenvatting

Activiteit van zogende boommarter-vrouwtjes (*Martes martes*) in Nederland

In de periode 1998-2007 werden in het Drents-Friese Wold en de boswachterijen Veenhuizen en Borger door temperatuurmetingen in de nestholte bij 16 nesten het gedrag van boommartermoertjes (*Martes martes*) bestudeerd in de eerste negen weken na de geboorte van de jongen. De nesten bevonden zich in oude boomholten van de zwarte (*Dryocopus martius*) en de groene specht (*Picus viridis*). De temperatuur in de nesten werd gemeten met een programmeerbare datalogger waarvan de temperatuursonde tot binnenin de nestholte was geïnstalleerd. Uit de temperatuurveranderingen die optraden bij contact met de sonde door het moertje kon worden afgeleid op welke momenten het moertje het nest binnenkwam dan wel verliet. Het aantal jongen varieerde van een tot vier. Het aantal dagen dat de nestholten in gebruik waren varieerde van 45 tot 70 waarna het moertje de jongen verplaatste naar een andere locatie, mogelijk veroorzaakt door gebrek aan ruimte voor de opgroeiende jongen. De tijd dat de moertjes bij de jongen doorbrachten, was in de periode voor het spenen van de jongen (in de zesde week) significant langer dan in de periode daarna. Voor het spenen bracht het moertje gemiddeld 13,8 uren door bij de jongen in het nest, in de speenperiode was dit gemiddeld 9,1 uren. De tijd dat het moertje voor het spenen buiten het nest verbleef was gemiddeld 5,3 uren en in de speenperiode gemiddeld 6,1 uren. De activiteit van het moertje vertoonde een duidelijk dag- en nacht-ritme, met name in de periode voordat het spenen van de jongen begon. In de eerste zeven dagen bleven de moertjes tijdens de gehele daglichtperiode bij de jongen in het nest. Er werden toen alleen korte uitstapjes gedurende de nacht gemaakt. Vanaf de tweede week begon het moertje met langere tochten. Naarmate de jongen opgroeiden, werden deze tochten steeds langer, terwijl de verblijftijd bij de jongen afnam doordat de moertjes steeds vroeger in de avond en middag vertrokken en het tijdstip van terugkomst vrijwel constant bleef, namelijk tussen middernacht en zonsopkomst. Dit patroon hangt samen met de groeiende energiebehoefte van moertje en jongen. Lange tochten werden vrijwel altijd gevolgd door lange rustperioden in het nest en korte tochten door korte rustperioden. Na de zesde week was er nauwelijks nog sprake van een bepaald dag- en nacht-ritme in nestbezoek. De uitstapjes van het moertje waren variabel qua tijdsduur en lagen verspreid over het gehele etmaal, een activiteitspatroon dat in verband kan worden gebracht met de ontwikkeling van de jongen die vanaf ongeveer de zevende week worden gespeend met de overgang naar vast voedsel.

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