The pine marten (*Martes martes*) population in a wooded coastal dune area in the Netherlands

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Abstract: This article presents the findings of a long-term study on the population structure, social organization and spatial behaviour of pine martens (*Martes martes*) in a forest area in the Noordhollands Duinreservaat, a coastal dune reserve in the Netherlands. A rich dataset of the pine martens inhabiting the area was generated by using camera traps to record the individually unique bib patterns of the martens. Based on the data collected, a database was compiled that allowed analysis of where, and when, the individuals were registered. A total of 9892 images of pine martens were recorded, and in 78% of these cases, the pine martens could be individually identified. In the four-year period between 2020 and 2023, a total of 64 individuals were recognized in the research area, which covered about 1500 ha. Many of these individuals were followed for long periods of time and each had its territory or at least a home range, with a high population density of pine martens of 2.2-2.8/km2. On average, two different pine martens occurred at each camera trap location. At one location, seven different individuals were seen. However, at two locations no pine martens were registered. Recording the date and time of the recordings provided insights into the martens' activity patterns and allowed the creation of an extensive annual overview on a two-weekly and half-hourly basis. The individuals observed could be classified as kittens (first calendar year), territorial males, territorial females, and non-territorial (sub)adults. These non-territorial animals were females in their second or third calendar year and males in their second, third and one even in its fourth calendar year. By deploying camera traps, 32 subadult pine martens, which had a home range, but no territory, were monitored during these four years. Several were born in the research area, appeared on video for the first time with their mother and were followed in subsequent years. This provides insights into the social behaviour of pine martens in a family context. Usually, two female partners live in the territory of an adult male, together with several (sub)adult pine martens, each with their own home range within the boundaries of the territorial male. The number of (sub)adults in each adult male's territory can vary from year to year. Social interactions were filmed, including growing young males playing with their mother's new generation of kittens.

Keywords: pine marten, *Martes martes*, camera traps, bib patterns, population structure, reproduction, social organization, spatial behaviour, daily activity pattern.

Introduction

Historical pine marten sightings in the Dutch province of North Holland are rare. The first confirmed sighting of a pine marten in Noord-Holland was made in the mid-1990s (Broekhuizen et al. 2016). Since the turn of the Millennium, pine martens have begun to colonize Noord-Holland. A study of the population size and structure was started shortly after the first pine marten was seen in 2006 in the Noordhollands Duinreservaat (NHD), a nature reserve at the coast of the North Sea.

Pine martens are mainly active in the night, rather secretive and thus difficult to observe. It is only after the advent of transmitter technology, DNA analysis and camera trap tech-

niques that a comprehensive picture of how pine martens live have emerged. It is clear from the literature that the densities and size of pine marten home ranges and territories greatly depend on the habitat and the available food supply (Brainerd et al. 1994, Balestrieri 2023). Pine martens are omnivores, although their diet mainly consists of mice. Male pine martens will mate with several females in one breeding season. Pine martens often exhibit intra-sexual territorial behaviour: i.e. male territories exclude other males, and female territories exclude other females (Balharry 1993, Birks 2017, Balestrieri 2023). Young male pine martens have an extended subadult stage in which maturity is delayed until they have passed their third birthday. Young female pine martens reach sexual maturity in the year following their birth, but because of the long period of delayed implantation they do not first give birth until their third calendar years (Birks 2017). Little is known about the spatial behaviour of these non-territorial individuals compared to territorial male and female pine martens.

This study on pine martens started in 2007. It is important to record the pattern of their bib is in order to recognize pine martens individually. It has become clear that individual pine martens can be uniquely identified by their bib patterns (Birks 2017). This can be done by making pictures or videos during an encounter with a pine marten with good quality camera equipment, but until 2011 only few pine martens were photographed and individually recognized. In 2011, the first camera traps were deployed. In 2012, a large-scale study with camera traps was carried out. Many pine martens were recorded at different locations, but individual recognition of the bib pattern was not possible at that time (Hamers et al. 2013). It wasn't until 2019 that the method and technology of camera traps were good enough to identify martens individually using camera traps. The use of these new cameras in 2019 provided images of different male pine martens at the same location. This was a strong indication

Figure 1. Location of the study area.

that there were subadults in the study area. To improve our knowledge of how many individual pine martens were around we started to intensively use high-quality camera traps. A method that was continued in the following years. 'Using this technique, the goals of this study were to determine the number of pine martens in the NHD, to clarify family relationships and to determine population structure by sex and age classes of the pine marten population in the NHD.

Materials and methods

Study area

The Noordhollands Duinreservaat (a Natura 2000 site) is a 5300-hectare forest and coastal dune area between Wijk aan Zee and Bergen (in the province of Noord-Holland) (Figure 1). A third of this area consists of forest. Since 2007, research into the occurrence of the pine marten has been conducted in most of the forested part (87%, ca. 1500 ha) of the Noordhollands Duinreservaat.

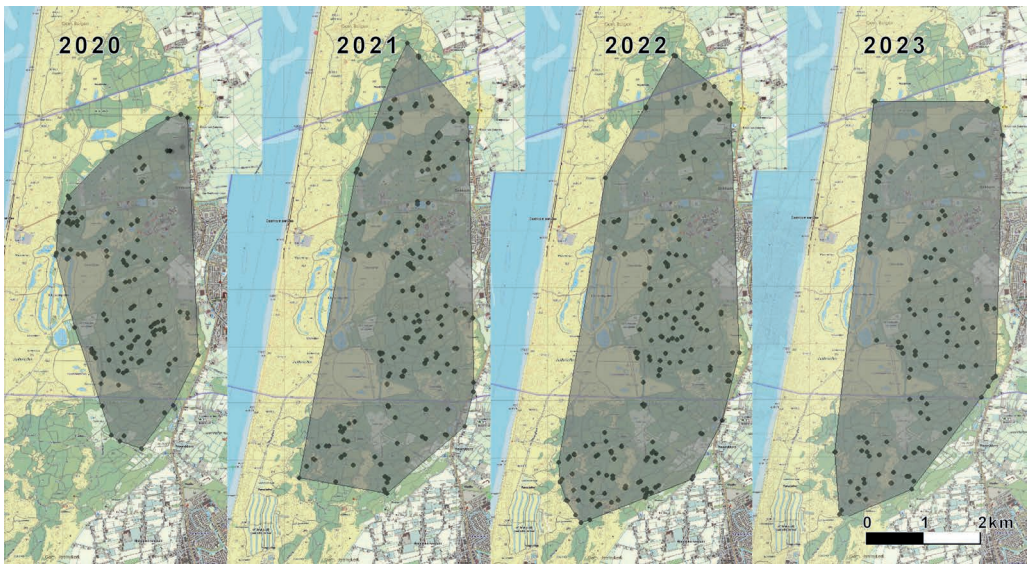


Figure 2. An overview of where camera traps were located each year. On average, the cameras remained at one location for three weeks.

The largest part of this forest was in use from 1820 and, until 1940, wood was harvested for various purposes. The forested surface consists of 12% coniferous wood and 88% deciduous forest. The deciduous trees belong to the native flora and are planted in places where they have been able to develop into natural dune forests. The most important tree species that occur are oak (*Quercus robur*) and birch (*Betula* spp.). In addition, species such as maple (*Acer* spp.), beech (*Fagus sylvatica*) and poplar (*Populus* spp.) occur. Provinciaal Waterbedrijf Noord-Holland (PWN), which combines the roles of being a drinking water company and nature management organization, has being trying to convert the coniferous forests into more natural deciduous forests. The coniferous tree species, mostly black pine (*Pinus nigra*), are not native flora. The shrub layer contains species such as hawthorn (*Crataegus* spp.), privet (*Ligustrum vulgare*), holly (*Ilex aquifolium*), dewberry (*Rubus caesius*), wild honeysuckle (*Lonicera periclymemum*), American bird cherry (*Prunus serotina*), alder buckthorn (*Frangula alnus*), wild rowan (*Sorbus aucuparia*) and spindle tree (*Euonymus europaeus*). To maintain openness, PWN uses large grazers, such as Exmoor ponies, Highland cattle, sheep, goats and Holstein-Friesian cattle, which are to be found in many places in the research area.

A main road runs along the east side of the site that separates the forest from residential areas and the agricultural landscape. The western border is the transition to an open dune landscape. To the north and south there is partly forest and open dune area. There are many walking and cycling paths in the area, which are used intensively between sunrise and sunset. There are three camping sites in the research area.

Camera trap set-up

From 2020 to 2023, ten camera traps were deployed throughout the year and were moved every three weeks (Figure 2). During the period with young pine martens, cameras of an older type were sometimes added. The following types of camera traps were used: Bushnell TROPHY CAM HD Brown, Bush-

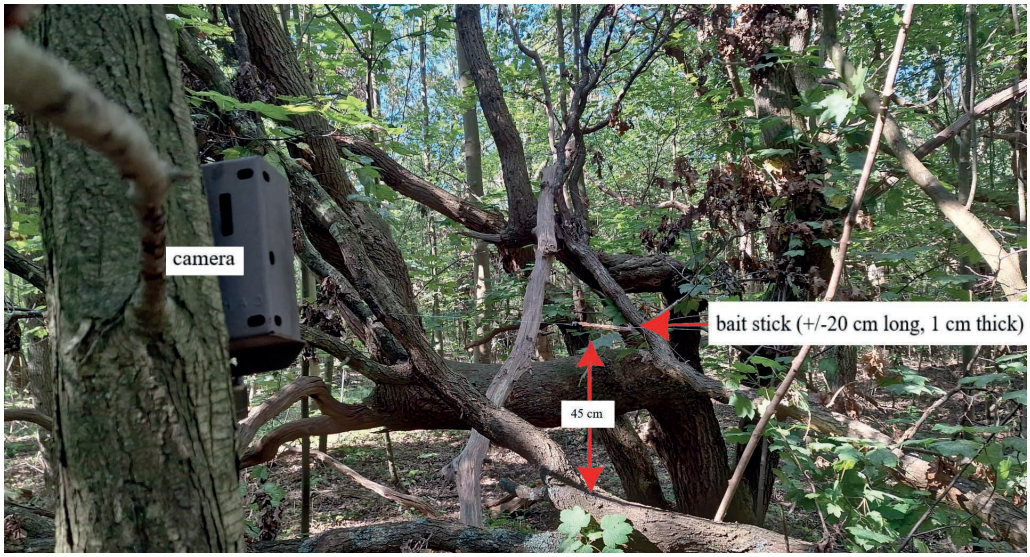


Figure 3. Camera trap set-up – location 23-116.

Figure 4. Camera trap setup snapshot location 23-116: night and day recordings.

nell Nature View HD Max, Stealth Cam DS4K, Reconyx Hyperfire 2 and Maginon WK4HD. These were replaced during the research by Browning 2021 Recon Force ELITE HP4 and Browning 2022 Recon Force Elite HP5 cameras. In front of the camera trap, a bait stick (ca. 20 cm long, 1 cm thick), was hung at 1.5 to 3 metres from the camera and approximately 45 cm above the ground, tree trunk or branch. A small amount of peanut butter was spread on the bait stick, but also on some branches / trunks that were visible on the camera, a dried plum was divided into four pieces and mounted on the bait stick and branches with a screw. This created a set-up in which a pine marten had to stand upright to reach the bait, allowing the camera to film the marten's bib pattern (Figures 3 and 4). The camera traps were checked twice a week. During the inspection new bait was applied, the images were viewed in the field and camera trap set-up adjustments were made where possible to increase the chance of making more recognizable images of the bib pattern.

Analysis

For the analyses of bib patterns, unique ID cards (Figure 5) were created by hand for each individual. ID cards consist of a standard pine marten drawing where the bib pattern is drawn plus a compilation of snapshots of this pattern from videos at different angles and

Figure 5. Example of an ID card. On the left a drawing of a bib, on the right compilations of stills from videos of the same individual taken during the day and at night and from different angles.

Table 1. Annual differences from four years of camera trap research: research year and area, number of locations, number of film observations, number of individuals recognized and density.

2020	2021	2022	2023
994 Ha	1553 Ha	1721 Ha	1575 Ha
137 unique locations 1622 images	211 unique locations 2725 images	230 unique locations 3050 images	176 unique locations 2495 images
22 unique pine martens	41 unique pine martens	49 unique pine martens	40 unique pine martens
Density 2.3 per km²	Density 2.6 per km²	Density 2.8 per km²	Density 2.5 per km²

lighting. This is manual work using a photo editing programme that can work with layers. In this way the bib pattern can be traced. The GPS location, camera name, individual ID and the date and time of each image were registered. Sex determination was mainly done by the visible scrotum of males and the puffy nipples of females. It often happened that the gender could only be determined after several registrations. In the second calendar year, especially during the mating season, this became easier. Kittens filmed with a female in May, June and July were assumed to be her offspring.

By plotting the GPS coordinates of each pine marten on a map, a picture emerged of which pine marten was observed where and which individuals shared locations. To estimate the size of the home range of individual martens, minimal convex polygons were calculated (Paterson 2018, https://www.r-project.org/). Although minimum convex polygons are commonly used to estimate home range sizes, they may potentially include areas that are not visited by the individual and thus result in an overestimation of the home range size. This also applies in reverse, i.e. pine martens can also occur outside the minimum convex polygon. Since data from open terrain and outside the research area are missing, it was not possible to make a good estimate of the home range for each individual.

Results

Overview of data per year

Over the study period (2020-2023), camera traps at 723 locations resulted in a total of 9892 registrations of pine martens. Of these registrations 78% were of sufficient quality to distinguish unique individuals, resulting in a total of 64 individuals (Figure 6, Table 1), with the exception of the kittens which were seen

Figure 6. Individual pine martens that were recognized over four consecutive years by their bib pattern. Each pattern has been traced using video fragments.

for only a short period and who probably died before becoming independent or dispersed from the study area.

Turnover in the pine marten population

In 2021, the survey area was extended by 559 hectares. The six females and three males seen in this area in 2021 were also present in the area before 2020. Figure 7a shows the total number of observations of pine marten individuals per quarter, classified by life stage per sex.

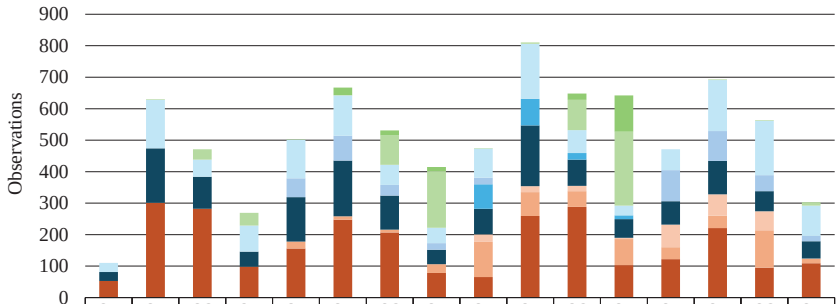
Not all 64 unique pine martens were present at the same time. On average, 15 territorial females, seven territorial males and ten subadults were recorded each year. In the four-year study period, five territorial females, three territorial males and 18 subadults disappeared without trace. During this period five traffic victims were found, two 2nd calendar year males (2 June 2021 and 22 June 2021), an unknown, presumably young, female (7 September 2022) (based on the slight wear of the teeth) and two adult females (8 July 2021 and 5-13 May 2023).

Subadults, especially males, may be present in their father's territory for several years. Figure 7b shows the number of individuals present in each quarter of each year. The unique individuals are divided into life stages and by gender. The 1st of January has been taken as the division date between the life stages. A pine marten in its first calendar year is classified as a kitten.

Young females become sexually mature in their 2nd calendar year. Nine 2nd calendar year females could be followed during this period, and all appeared on camera in their 3rd calendar year. Two of these young females appeared on camera with young. In spring (lactation period) lactation was observed in other young females, which may include phantom pregnancies. Adult females who gave birth to kittens that spring usually appeared on camera with kittens for the first time in early July, some time after their reproductive status was noticed by showing signs of lactation. These 3rd calendar year females had established their own territories at the edge of their mother's territories. One of these 3rd calendar year female pine martens disappeared from her territory in August 2022, eleven months later this "missing" female was caught by a camera trap in a narrow forest plot on the edge of the research area. She came in front of the camera together with a new young. She had changed her territory. Her young, born in 2022, were regularly seen in her parents' territory, where the neighbouring female was now staying.

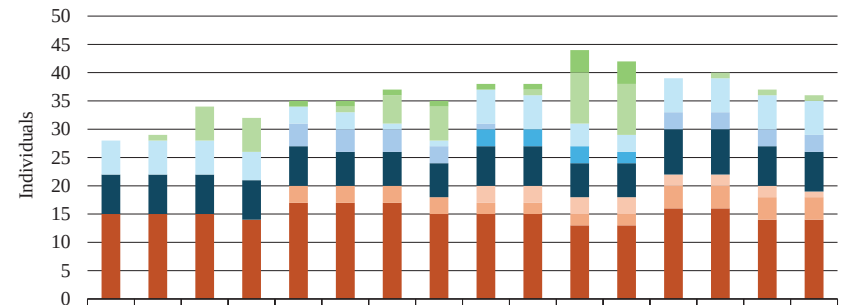
Males may reach sexual maturity in their 2nd calendar year (Stier 2012, Broekhuizen & Müskens 2000), but generally do not show signs of sexual activity until they reach the

(a)



	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
	2020				2021				2022				2023			
New	0	0	0	0	1	24	16	13	1	1	20	115	0	0	0	0
kitten	0	2	33	40	0	1	93	180	0	3	96	235	0	2	2	11
2nd calendar year males	29	154	54	83	122	128	64	49	92	175	73	31	66	162	173	96
3rd calendar year males	0	0	0	0	60	79	34	21	21	0	0	0	99	95	51	17
4th calendar year males	0	0	0	0	0	0	0	0	78	84	21	12	0	0	0	0
male adult	28	173	102	48	141	177	108	46	81	193	83	59	74	106	64	55
2nd calendar year females	0	0	0	0	0	0	0	0	24	19	17	4	72	68	60	1
3rd calendar year females	0	0	0	0	22	11	9	28	112	76	50	83	38	39	119	14
female adult	53	301	282	98	156	247	207	78	65	259	288	103	122	221	95	109

(b)



	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
	2020				2021				2022				2023			
New	0	0	0	0	1	1	1	1	1	1	4	4	0	0	0	0
kitten	0	1	6	6	0	1	5	6	0	1	9	9	0	1	1	1
2nd calendar year males	6	6	6	5	3	3	1	1	6	6	4	3	6	6	6	6
3rd calendar year males	0	0	0	0	4	4	4	3	1	0	0	0	3	3	3	3
4th calendar year males	0	0	0	0	0	0	0	0	3	3	3	2	0	0	0	0
male adult	7	7	7	7	7	6	6	6	7	7	6	6	8	8	7	7
2nd calendar year females	0	0	0	0	0	0	0	0	3	3	3	3	2	2	2	1
3rd calendar year females	0	0	0	0	3	3	3	3	2	2	2	2	4	4	4	4
female adult	15	15	15	14	17	17	17	15	15	15	13	13	16	16	14	14

Figure 7. Total number of observations of individual pine martens (a) and of individuals (b) per quarter, classified by life stage and gender. Q1, Q2, etc. refer to quarters of the year.

age of three years (Balharry 1993, Kleef & Wijsman 2015, Balestrieri 2023).

During this study, two 4th calendar year males established their own territories. A male born in 2019 was found in January 2022 at another location in the study area. Another male, born in 2019, took over a territory from his father. This father, who was followed from 2018, was seen in 2020 in several places outside his own territory and the last sighting was on 15 May 2022, limping in front of a camera trap. In 2018 this male had his own territory.

Table 2. Daily activity patterns of pine martens in the course of the year, by two-week period, cumulated over the years 2020-2023. Numbers represent the number of pine martens recorded by the camera traps. A darker grey hue indicates more records, i.e. a higher activity level. Recordings with imprecise times are not included.

week number / Time	01+02	03+04	05+06	07+08	09+10	11+12	13+14	15+16	17+18	19+20	21+22	23+24	25+26	27+28	29+30	31+32	33+34	35+36	37+38	39+40	41+42	43+44	45+46	47+48	49+50	51+52	Total
0:00	8	5	18	8	15	13	17	26	24	43	40	40	33	31	40	31	27	19	28	15	18	17	14	13	7	12	562
0:30	7	8	11	5	12	22	6	15	17	38	35	32	18	13	26	31	14	24	14	13	8	19	6	10	9	14	427
1:00	2	6	11	9	12	16	20	17	21	26	27	27	19	17	17	24	22	38	19	10	11	9	13	3	6	17	419
1:30	4	7	13	5	9	25	12	16	24	22	26	20	18	21	11	27	19	19	15	11	14	15	10	7	7	8	385
2:00	10	12	13	13	15	13	6	22	15	24	15	18	15	14	17	13	13	26	31	5	15	9	9	11	10	9	373
2:30	3	8	7	6	13	16	15	19	17	22	21	21	20	16	12	11	14	28	9	11	11	10	11	4	9	17	351
3:00	7	20	11	5	6	8	17	14	19	18	19	20	17	24	16	15	16	21	16	9	16	6	8	4	2	9	343
3:30	6	11	9	8	6	10	18	11	22	22	25	15	18	9	19	14	18	13	13	9	17	24	10	14	5	13	359
4:00	4	10	9	6	9	8	11	9	19	28	22	16	19	9	15	26	16	22	13	8	11	18	11	13	6	10	348
4:30	4	7	9	9	11	16	11	19	15	17	12	17	14	22	23	20	10	14	16	9	7	9	8	4	7	15	325
5:00	4	5	11	3	2	7	10	16	18	18	14	19	6	6	13	10	15	11	16	6	12	5	10	9	13	8	267
5:30	6	5	7	3	7	4	4	2	12	11	10	11	10	13	9	11	11	14	7	13	9	6	5	8	4	8	210
6:00	6	7	10	2	2	5	6	5	2	11	6	12	14	11	8	4	4	7	11	5	3	7	2	7	2	10	169
6:30	8	4	3	5	1	1	3	1	3	3	6	8	4	8	6	2	4	8	2	4	8	7	12	3	2	11	127
7:00	3	2	2	5			1	2	4	3	5	8	3	7	5	4	1	5	5	7	3	8	2		4	2	91
7:30		1	2	1						1	2	9	8	4	4	3	3	8	1	4	2		1	1	7	2	64
8:00	2	1	3						2	1	2	3	7	7	6	1	4	5	2	4			2		3	2	57
8:30									1	1	8	4	7	9	2	4	3	3	3			2	1	1		2	51
9:00									2	1	3	2	5	7	5	1	6	4	4	1	1	3				1	46
9:30							1				4	3	4	5	4	4	4	5	1	2				1			38
10:00									1		7	2	1	1	2	1	6	2	2	4	3						32
10:30					1				1	2	5	1	6	2	1	6	1	2			1						29
11:00				1			1			1	1		1	6	2	2		4	4		1						24
11:30								1			2	1	3		2	2		3	2	3							19
12:00											2	2	4		1	1	2	4	1	2							19
12:30								1			2	3		1	3	2		2			2						16
13:00										1	5	4		1	1		1	1									14
13:30										1	1		1	3	3			2									11
14:00					1							4	2		1		2	1	2								13
14:30										3	2	3	2	2	2		2		2	1	1					1	21
15:00										2	2	2	1	3	2	3		2		1	1						19
15:30											1	2	2		5	2		1	1								14
16:00										3		5	3	3	2		3										19
16:30				1						1	3	7	3	1	2												18
17:00							1	1	1	2	7	7	3	3	2	3	2			1						1	34
17:30	5	1			1	1	2	1	3	2	8	5	2	1	7	2	1	2					2	6	3	5	60
18:00	3	12	3		2				2	3	4	5	5	2	7	2	3			3			6	15	6	22	105
18:30	12	7	10		4	1	1		1	5	8	9	7	4	5	5	2	1	2			1	9	12	13	24	143
19:00	5	10	15	18	20	6	2	1	4	4	7	8	8	4	3	3	3	3	1	3		3	12	16	17	19	195
19:30	9	7	16	16	23	24	6	3	3	4	6	8	8	7	4	4	6	2	4	2	9	15	15	13	14	21	249
20:00	5	7	9	15	19	18	17	3	5	4	9	11	3	7	8	4	3	9	6	13	17	12	16	15	13	17	265
20:30	12	21	18	23	16	29	14	14	6	10	8	13	10	7	8	6	9	13	17	10	13	23	10	10	14	15	349
21:00	6	11	10	16	18	29	27	30	19	21	10	16	16	14	10	6	4	18	22	13	26	19	10	16	17	13	417
21:30	4	18	11	14	17	15	36	30	43	17	22	17	10	14	15	12	15	20	21	27	12	12	10	10	12	14	448
22:00	5	8	19	13	10	18	30	36	46	39	27	29	16	24	27	23	24	35	23	27	18	14	9	12	3	14	549
22:30	9	8	8	12	6	21	25	43	48	52	39	30	24	36	41	22	20	29	26	21	18	16	10	10	10	10	594
23:00	9	14	11	14	21	26	18	35	48	57	56	44	29	37	50	35	41	22	18	15	20	15	17	8	9	10	679
23:30	8	9	13	18	11	17	24	26	36	31	31	31	28	30	28	25	21	25	18	15	12	12	10	13	9	11	512
Total	176	252	292	254	290	369	362	419	504	575	577	574	457	466	502	427	395	497	398	307	320	316	271	269	243	367	9879

One 4th calendar year male (born in 2021) was, at the time of writing of this article (on 1 November 2024), still present in his father's territory. The father showed up at the same camera location. He came into view together with his father. This young male is now 42 months old.

The gender of four animals seen in 2022 could not be determined. A total of 27 females and 33 males were identified.

Activity patterns

The large number of observations made it

Figure 8. The female is on the left, kitten in the middle and 2nd calendar year male on the right. Only the kitten shows no moult contrast in the tail.

possible to create an overview of half-hourly activity patterns in the course of the year (in two-week periods) over the study period of 2020-2023 (Table 2). To create this overview the data was organized and summarized by two weeks and half hours. A pivot table was created from this.

Pine martens are more active during warmer weather than cold periods, but other events also have an influence, such as social interactions over the course of the year. In January nothing much happens. In February pregnancy begins with the implantation of blastocysts. The new kittens are usually born in early April, open their eyes and mothers go out more to find food for the kittens. At the end of June the kittens appear in front of the camera and sometimes encounters are filmed with the subadults living in the territory. In early July the mating season begins, which lasts for some weeks. In July, some kittens start dispersing and may be seen in other males' territories, while other kittens seek a home range in their father's territory. Each subadult, male or female, has its own home range within their father's territory. The mating season ends in August. In September some kittens still follow their mother on some days. Also new animals will appear in the area for a short period. Activity decreases in November and December. So far, the data show no particular period of the year for the subadults to leave the area to establish their own territory.

To determine the mother relationship, I registered which mother the kittens were seen with. The kittens were on camera from the beginning of June. Until August they are recognizable by their smaller size, uniform coat and thinner tail. Pine martens moult twice a year, in spring and late summer. Figure 8 shows the tail shape of a female, a kitten and a 2nd calendar year male. Only the kitten shows no moult contrast in the tail. The summer moult lasts until August. The old fur that still has to moult is long and fluffy and the difference in tail shape between kitten, subadult and adult is clearly visible in June and July. The males and subadults finish the summer moult at the end of July, and the females have their young a few weeks later. The distinguishing difference in fur between kittens, adult and subadults disappears by August.

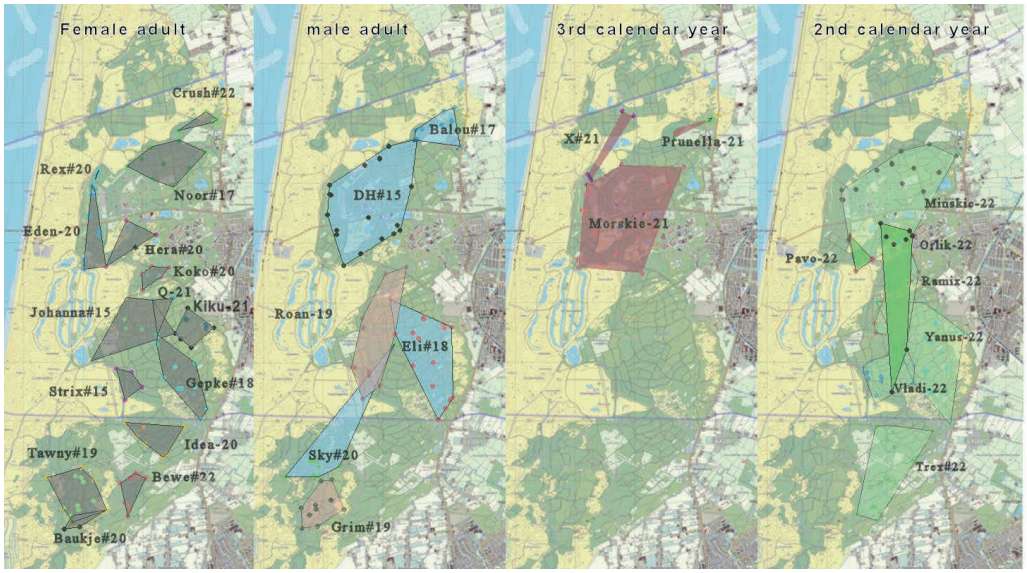


Figure 9. Spatial distribution of the home ranges of pine martens in 2023 (individuals recognized in camera trap images) in the NHD, divided into adult females, adult males and resident yearlings of one and two years old. The last two digits of a marten's name is the year of 1st recording. If the character before it is a dash (-) it means that it is seen together with its mother. # means it was unclear who the mother was.

Table 3. Overlap of home range/territory of different pine martens.

overlap of home range/territory of different pine martens	
Adult male – adult male	Males have their own territory. Occasionally an adult male was registered within the home range of another adult male. This was during the mating season.
Adult female – adult female	Females have their own territory. Sometimes there is overlap at the edges. Occasionally an adult female was registered within the territory of another adult female.
Subadults – adult males	Each subadult has its own home range. The home range is within the father's territory and may overlap with multiple female territories. Every now and then a subadult appeared together with the territorial adult male in front of the camera. The territorial of an adult male is larger than that the home range of a subadult. The home range of a subadult falls wholly or largely within the male's territory.
Subadult – adult females	The home range of subadults may overlap with multiple female territories. Every now and then a subadult appeared together with the territorial female in front of the camera.
Subadult – subadult	The home range of subadults may overlap with other subadults. One or several subadults together were regularly observed at camera locations. Subadults from different years of birth have appeared together in front of the camera. Subadults are tolerated in the territories of adults and the home ranges of other subadults. The size of the home range of a subadult increases as they grow older. Densities above 2 pine martens per km² are a sign that subadults are present in that area.

The kittens are still recognizable by their playful behaviour, which gradually decreases. In October one can hardly see any difference in behaviour in front of the camera. In this way the mothers of 23 kittens could be determined.

Table 4. Number and location of individual pine martens recorded in 2023. Once sufficient registrations and locations had been collected, the surface area (minimum convex polygone) was calculated in ha. When an individual was registered at only one of two camera locations, including one case of three locations, there is a question mark for 'surface area'.

Detailed data on pine martens registered in 2023 in the NHD									
individual	registrations	locations	ha	individual	registrations	locations	ha		
female adult				Subadult in 3rd calendar year				mother	Father ?
Crush#22	33	6	6.8	Eric#21	10	1	?		
Koko#20	41	7	8.5	Mart-21	17	3	?	Miep#21	?
Baukje#20	26	4	8.5	Morskie-21	210	30	225.1	Noor #17	DH#15
Q-21	63	5	10.2	Prunella-21	33	7	6.1	Crush#22	Balou#17
Strix#15	39	6	11.5	X#21	9	2	?		
Move#21	43	10	14.0	Subadult in 2nd calendar year				mother	Father ?
Kiku-21	137	12	21.4	Orlik-22	53	8	92.8	Hera#20	DH#15
Hera#20	9	3	22.5	Pavo-22	39	6	9.4	Hera#20	DH#15
Eden-20	62	15	27.4	Peppi-22	1	1	?	Koko#20	DH#15
Idea-20	31	7	27.9	Minskie-22	115	20	215.1	Noor #17	DH#15
Tawny#20	49	13	51.6	Olly-22	4	2	?	Miep#21	?
Gepke#18	54	10	53.7	Ramix-22	61	11	57.8	Johanna#15	Roan-19
Noor #17	49	9	56.5	Shawka#22	4	3	?		
Johanna#15	35	8	71.0	Trex#22	113	21	104.3		
Miep#21	2	2	?	Vladi-22	112	18	48.4	Daffy-20	Roan-19
Rex#20	54	2	?	Yanus-22	190	23	154.4	Gepke#18	Eli#18
male adult									
Balou#17	3	2	?						
DH#15	49	19	188.5						
Eli#18	44	18	111.8						
Grim#19	80	12	35.6						
Roan-19	69	13	100.4						
Sky#20	26	9	87.7						

Homerange of subadults

Little is known about the home ranges of young pine martens, but this study did shed some light on this (Table 3). With the collected data, the home ranges or territories of each individual can be plotted on a map (Figure 9) and an indication of the area of the habitat can be calculated. Using R-studio, the home ranges of the individuals that were observed at, at least, four locations were calculated (Table 4, showing the situation in 2023 for female animals that had given birth, adult males, one- and two-year olds). Only registrations from 2023 have been included. The home ranges at the edges of the research area indicate part of the territory, as adult males are known to make occasional forays into neighbouring territories (Birks 2017).

Martens most often appeared alone in front of the cameras. Only 1% of the registrations were of multiple animals, excluding mothers with their kittens, these are encounters between two resident pine martens or with yearlings or yearlings with a territorial pine marten. No territorial aggressive encounters were registered.

Some of these encounters were subadults with their mothers and kittens. These subadults played with the kittens.

Figure 10. Snapshot of film of a yearling (15 months old) making a suckling movement with its mother (standing in the middle). Right, a kitten from 2023. The QR code is a link to the film on YouTube - https://www.youtube.com/watch?v=2lZpSQaU--U.

Figure 11. Playful behaviour between 2nd calender year male or subadult (left) and two kittens. The QR code is a link to the film on You Tube: https://www.youtube.com/watch?v=SczghWI0Ovk&t

Several unique encounters have been recorded between subadult males playing with kittens in the presence of their mothers. The subadults displayed playful behaviour. In one film, a male subadult tries to drink from its mother (Figure 10). Subadults also display playful behaviour in the presence of adults (Figure 11). The adults did not respond to or correct this behaviour.

Table 5. The number of unique individual pine martens recorded during the day over the course of the year, by two-week period, cumulated over the years 2020-2023. The numbers reflect the pine marten recordings captured by the camera traps.

Number of days active unique pine martens in 2020/2023 biweekly	01+02	03+04	05+06	07+08	09+10	11+12	13+14	15+16	17+18	19+20	21+22	23+24	25+26	27+28	29+30	31+32	33+34	35+36	37+38	39+40	41+42	43+44	45+46	47+48	49+50	51+52	Total
New										1	1	1			1		1		3	1	1						7
kitten										1		1	2	3	2	3	6	7	2		1	2	1	1	1		13
2nd calendar year males				2	2	1	3	3	5	5	6	8	9	5	4	2	1	4	1	1					1	1	16
3rd calendar year males			1			1	2	1	1	2	3	5	4	3	3												8
4th calendar year males						1	1		1		2	2	1	1													3
male adult						3	4	4	4	7	6	8	8	5	4	4		2									9
2nd calendar year females					2	1	3	2	4	1	2	2	2	4	4	2	2	1									6
3rd calendar year females							1		1	1	1	2	3		1			2	2	1							5
female adult			1		2	6	6	9	11	14	10	10	10	10	8	9	7	6	6	3		1			1		19
Total			2	2	6	13	20	19	26	31	26	32	30	27	25	18	16	19	14	5	2	3	1	2	3	1	57

Discussion

The total number of bi-weekly registrations was lowest in January, with an increase from March onwards, and a peak from mid-May to late September, after which it gradually decreased (Table 2). Research in Białowieża National Park in Poland (Zalewski 2000, Zalewski & Jędrzejewski 2006, Balestrieri 2023), revealed that martens are active for an average of 8.5 to 9 hours per day. The duration of activity is lowest in winter (approx. 15% of the day cycle), and highest during the mating season (approx. 50%; Zalewski 2000). The mating season starts around the 1st of July and lasts for several weeks. These activities were measured differently in the two studies but the pattern of low activity in winter is similar.

Table 5 shows the number of unique individual pine martens recorded during the day over the course of the year, by two-week periods. In the period from late March to early August the number of active unique adult males is higher during the day, with a peak from mid-May to early August. This may indicate that the mating season starts earlier than in Poland. However, this peak is also seen in subadult males. Another explanation may be in the food supply. Birds, mainly Passeriformes, are on average the third item in order of importance in the pine marten's diet, especially in Mediterranean Europe, while medium-sized and large mammals (lagomorphs and ungulate carrion, respectively) are generally more frequently eaten at high latitudes (Zalewski 2004, Balestrieri 2023). In a breeding bird inventory in the NHD, Slaterus (2021) makes no special mention of (the arrival and increase of) pine martens as a possible explanation for declining bird populations, except for green woodpeckers (*Picus viridis*). For other individual bird species at a local level, a negative effect cannot be ruled out completely. Possibly, pine martens in the NHD eat fewer birds than other studies have shown. Future studies may shed more light on this.

Research in Białowieża National Park found that males show longer activity periods (four hours on average) than females (three hours) (Zalewski & Jędrzejewski 2006). In this study, the number of activity periods per day varied from one to six (average 2.6) and increased as the ambient temperature increased. In February-March it was 2.8 hours/day of activity and in June-July 12 hours/day. This method does not allow for measuring activity periods. Visits by the same pine marten were recorded for each day. However, since there were no start and end times, it is not clear whether a second registration is part of the same, or a new, activity.

In a study by Stier (2012) all pine martens, including the males, reached sexual maturity at the age of 1¼ year. Broekhuizen & Müskens

(2000) found that in the Netherlands females and males also reached sexual maturity in their second summer. Remarkably, in the NHD, young pine martens older than 1¼ years, both female and males, had home ranges in territories of adult male pine martens. These individuals were only seen within the confines of one territorial male, probably their father.

The density measured in the NHD (which, excluding kittens, varied between 2.3 and 2.8 pine martens per km^2) is high compared to other reported studies. Most other areas in the Europe have a much lower density (Balestrieri 2023). The National Pine Marten Population Assessment in Ireland assessed pine marten presence and densities at 19 wooded areas across Ireland, using non-invasive survey techniques. Hair samples from pine martens were collected and analysed using molecular methods to determine individual identity details for each pine marten. Pine marten densities ranged from 0 to 2.60 individuals per km^2 of forest habitat in randomly selected study sites (O'Mahony et al. 2017). In the Netherlands, some volunteers carry out annual inventories. The results are published in the annual newsletter 'Marterpassen' of the Dutch Pine Marten Working Group. The densities in the NHD of 2.3 and more also generally exceed their findings. However, Hartman (2023) reported 2.3 inhabitants/km^2 in De Bilt in 2022 (58 pine martens on 25 km^2).

A population density greater than two is an indication that there are growing young animals in the area. These subadults leave the parental territory at a certain age. Female subadults can stay for up to two years, males for up to three years, possibly four years.

Regarding the use of attractant: Not every pine marten reacts the same to attractant. It is possible that individuals were missed. The attractant was often eaten by other animals. This makes it possible that individuals were at the location but were not registered. If pine martens are used to the attractant, they will return more often to the location.

With this method it must be taken into account that errors can be made when analysing images. By irregularly plotting location data on a map, incorrectly written locations can be discovered. When creating the day and night activity table, AM-PM recording errors emerged. Multiple pine martens can occur at one location. When making an ID card, it sometimes happened that, at the entry of a new individual, an ID card was made of two individuals. When analysing new images, this error came to light and was corrected retroactively.

Young male pine martens have an extended subadult stage in which adulthood is delayed until they have passed their third birthday (Balharry 1993, Balestrieri 2023). In this study, a subadult in his fourth calendar year old lived in another male's territory until at least November. The underlying theory is that territorial males have significantly higher testosterone levels than subadults from May to July (Balharry 1993, Balestrieri 2023). It is not known whether this 4th calendar year old male had lower testosterone levels than normal. However, there were fewer visible bald spots around the abdominal gland, possibly indicating less friction with the abdominal glands (Figure 12).

Conclusions

The following conclusions can be drawn from this study,

- A healthy pine marten population lives in the forest area of the Noordhollands Duinreservaat.
- Camera traps can be used to determine the size of a local pine marten population, provided that the pine martens are individually recognizable. This also provides insight into the surface area of an individual's home range. The home range sizes of adult females and males in this study area are very small when compared to data from Birks (2017), which indicate that the smallest home range for a female is 70 hectares and 171 hectares

Figure 12. Compilation photo of the abdominal gland spots of four different males in late July. From left to right: a male of at least five years old, a 2nd calendar year male, a 4th calendar year male, and a male of at least ten 10 years old.

for a male. The research area contains a lot of food for the pine martens, which means that territories are small and several subadults can simultaneously grow up in such a space. Several subadults were registered at several locations. This study shows that a territorial male shares his territory with one or more females, plus the growing young of these females. There is a good chance that he is the father of these subadults.

- A territorial female shares her territory with one and sometimes two territorial males, plus young animals, that are not yet reproducing. These young animals are her offspring or from neighbouring females who share the same territorial male. Subadults are tolerated in the adult's territory for a quite long period of time. They prefer to grow up in a home range within the territory of one adult male.
- Subadults can play a role in raising the new generation. They play and eat together with the territorial female and her young. Yearlings follow the older animals.
- Pine martens live solitary lives, although it should be noted that pine martens tolerate each other within family bonds.
- Female pine martens have their first young when they are two years old (in their third calendar year). Because of the delayed implantation of the blastocyst these young females have mated for the first time in the year before, in their second summer.
- Subadults also have their own home range.

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Samenvatting

De boommarterpopulatie in het bosgebied van het Noordhollands Duinreservaat

Dit artikel presenteert de bevindingen van een langdurig onderzoek naar het voorkomen van boommarters (*Martes martes*) in het Noordhollands Duinreservaat. Het gaat specifiek om de verzamelde gegevens van 2020 tot en met 2023, waarbij een rijke dataset werd

gegenereerd met behulp cameravallen, gericht op het vastleggen van het individueel unieke befpatroon van de boommarters. In de loop van het onderzoek werd in totaal 9892 keer een boommarter geregistreerd, waarbij in 78% van de gevallen het dier individueel kon worden geïdentificeerd. In het onderzoeksgebied van ca. 1500 ha konden in totaal 64 individuen gedurende een bepaalde periode gevolgd worden. Dit resulteerde in een hoge dichtheid van boommarters van 2,3-2,8/km^2. Door de datum en het tijdstip van de opnames vast te leggen, werd inzicht verkregen in de activiteitspatronen van de marters zowel overdag als 's nachts, waardoor een uitgebreid jaaroverzicht op tweewekelijkse en halfuurbasis kon worden opgesteld. De waargenomen individuen konden per kalenderjaar worden ingedeeld in territoriale mannetjes, territoriale vrouwtjes en opgroeiende subadulte dieren, die gedurende enkele jaren konden worden gevolgd. Vier jaar lang werden gemiddeld tien camera's gebruikt die elke drie weken verplaatst werden en twee keer per week werden gecontroleerd. Bij controle werd nieuwe lokstof aangebracht, werden de beelden in het veld bekeken en de opstelling zo nodig aangepast. De camera's werden strategisch zo geplaatst dat de boommarters met hun unieke befpatroon gefilmd konden worden. Er zijn ruim 10.000 beelden verzameld en geanalyseerd. Hierdoor kwam een database tot stand die duidelijk maakte waar en wanneer welke boommarters werden gezien. Gedurende de onderzoeksperiode konden 32 sedentaire boommarters worden gemonitord. Deze dieren zijn geboren in het onderzoeksgebied, kwamen voor het eerst in beeld met hun moeder en konden in de jaren daarna gevolgd worden. Hierdoor ontstond een beeld hoe de boommarters gebruik maakten van het terrein en welke individuen er zich bevonden. De boommarters verschenen bijna steeds alleen voor de camera. Eén procent van de registraties betrof meerdere dieren, vrouwtjes met jongen niet meegerekend; het ging daarbij om vriendschappelijke ontmoetingen, territoriale interacties werden niet geregistreerd. Enkele van deze ontmoetingen waren subadulte boommarters die samen met hun moeder en haar jongen van enkele maanden oud gezamenlijk in beeld kwamen. Deze subadulte boommarters speelden regelmatig met hun jongere broertjes en zusjes. Door gebruik te maken van locatiegegevens was het mogelijk de omvang van het leefgebied van deze individuen te schatten. Subadulte dieren hebben hun eigen leefgebied wat zich in een mannelijk territorium bevindt en waar het territorium van de moeder onderdeel van uit maakt. De bevindingen werpen licht op het gedrag en de ruimtelijke dynamiek binnen boommarterpopulaties.

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