

Spatial ecology and prey choice of tagged feral cats on Schiermonnikoog

M.Sc. Dissertation



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Spatial ecology and prey choice of tagged feral cats on Schiermonnikoog

M.Sc. Dissertation

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Abstract

Feral cats (*Felis catus*) inhabiting the island Schiermonnikoog, The Netherlands, are a potential threat for local prey species populations. To improve the understanding and retrieve more insight in the spatial ecology of this invasive predator, ten feral cats (5 male : 5 female; 5 adult : 5 subadult) were equipped with GPS tags and followed from May till July 2014. Spatio-temporal analyses were used. The home ranges we calculated using Minimum Convex Polygon and Kernel density estimators and tested for differences in sex, age and time. The displacement distance and habitat use was compared between day and night. Locomotive behaviour was compared between subjects using a pre-defined dimension dyad with daily movement variables. In addition, scats were collected and analysed on prey remains and compared with the prey present in the area.

Average 3-month home ranges were found to be 81 and 158ha using Kernel density 95% and Minimum Convex Polygon 95% home ranges respectively. Home range sizes were not significantly different between sexes or age classes. However, nocturnal home range sizes were bigger than the diurnal ones. The nocturnal habitat use did differ from the diurnal use, suggesting a small preference for short salt marsh vegetation during the night. The cats showed a higher nightly displacement (M=45m/15min) compared to during the day (M=22m/15min). The cats were very variable in their daily migration (range M=198-528m) and cumulative daily displacement (range M=1.5-4.1km). A new visualisation technique was proposed to identify differences and similarities between the feral cats and seemed to work well. Hares (*Lepus europaeus*) contributed the most to the diet in terms of relative prey volume, but Common vole (*Microtus arvalis*) was the most numerous prey item found in the scats.

In conclusion this study describes the spatial ecology of feral cats and give new insights in the behaviour of feral cats in a natural part of a Dutch Waddensea island. The home ranges of males are not necessarily bigger than female ones. They tend to use short salt marsh vegetation more during the night which could indicate they hunt on the nocturnal species foraging there like hares and rabbits. Bird remains are found in the scats which indicate a potential threat for the bird population by this invasive introduced predator. However in this research no indication is found they actively search and hunt on birds. Further research using acceleration data might be useful to better quantify their hunting behaviour.

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Disclaimer

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1 Introduction

The cat was domesticated for about 4,000 years ago and is now one of the most widespread invasive terrestrial carnivores (Long 2003). A domestic cat (*Felis catus*) reverted to a feral state is defined by Natoli (1985) and Liberg et al. (2000) as a cat that occupies areas for food and/or shelter and is unwanted or unowned. Feral cats are able to adapt to a wide range of environmental and climatic conditions (Courchamp et al. 2003). As a real generalist predator it can readily switch between prey items what enables it to thrive in an area with changing prey availability through different seasons (Fitzgerald & Turner 2000). Several studies indicate that this introduced species causes the decline or even extinction of local indigenous animal species (e.g. Fitzgerald & Turner 1988; Dickman et al. 1993; Burbidge & Manly 2002; Courchamp et al. 2003). Loss et al. (2013) estimate that feral cats in the United States and Europe annually kill 1.7 billion birds and 10.9 billion mammals. Lowe et al. (2000) listed the cat among the 100 World's Worst Invasive Alien Species.

Especially animal species that evolved without the presence of mammalian ground predators, thus that have no behavioural, morphological or ecological adaptations, are vulnerable for the effects of an introduced predator (Fitzgerald & Turner 2000; Bradshaw et al. 2012). This mainly occurs on islands. Because feral cats are introduced on almost all islands where human activity occurs, these effects can be severe. Medina et al. (2011, p.3509) reviewed 229 cases and showed that global insular feral cat populations "contributed to a minimum of 14% of all bird, mammal, reptile extinctions and the decline of at least 8% of critically endangered bird, mammal, reptile species".

Also Dutch islands are occupied by feral cats. Different studies (Niewold 1986; Langeveld 1987; Jansman & Müskens 2001; Hofman & Postma 2006; Op de Hoek 2012; Maris 2013) showed that the feral cats prey upon birds amongst others. On these islands the ground breeding birds are potentially extra vulnerable for the effects of this introduced, non-native ground predator. On Schiermonnikoog Langeveld (1987) indicated that the staple food (main prey) for cats were hares (*Lepus europaeus*) and rabbits (*Oryctolagus cuniculus*) with 60% and secondly birds with 30%. Op de Hoek (2012) and Maris (2013) analysed the ingested prey in 2011 & 2012. They suggest that the feral cats switched to the non-native Common vole (*Microtus arvalis*) as staple food (~60%) after its' introduction on Schiermonnikoog in 1992. They also calculated that almost 25% of Schiermonnikoogs' population of small breeding-birds was eaten annually. Schiermonnikoog lacks other mammalian ground predators and the Common voles are introduced. This makes the island especially interesting, because introduced non-native prey species, occurring in high densities, are often the main food source for feral cats. The feral cat population can grow due to the high availability of prey present and thus the impact on native species (e.g. birds) can become larger (Medina et al. 2011).

Besides the diet characteristics, spatial characteristics are important to understand the behaviour of the feral cats and also to assess their immersion in the environment. To understand the interaction of the feral cats with the area over time, spatio-temporal analysis are essential. The space use and movement behaviour are important because the habitat use is driven by the presence of prey (Recio & Seddon 2013) and Langeveld (1987) mentioned the circadian activity pattern of the feral cats is dependent on the active period of the prey species. In areas with many nocturnal prey species, the

cats will adapt their main activity period to the night. Locomotive behaviour, e.g. cumulative displacement distance or daily migration, is used to understand the spatial behaviour of a free ranging animal and is implemented in studies like Langham (1992) and Schai-braun (2012). Furthermore territorial analysis are often used to understand secretive free ranging mammals (Boyle et al. 2009; Laver & Kelly 2008; Worton 1989). The aggregation of the locations, e.g. per day, night, week, season or year can give insight in the space use by animals and is considered the home range of the animal (Powell & Mitchell 2012). Home range is defined by Burt (1943, p.351) as “that area traversed by an individual in its normal activities of food gathering, mating, and caring for young. Occasional sallies outside the area, perhaps exploratory in nature, should not be considered part of the home range.”

Feral cats behave very shy and reside in remote and widespread areas (Bradshaw et al. 2012), which make direct observation very challenging. It is impossible to measure body weights or get insight in population demographics like sex and age distribution visually. Therefore cats need to be captured and this is, until now, only done by Langeveld (1987) on Schiermonnikoog. She used live traps and caught 11 feral cats ranging between 640 and 6,025gm and six juveniles/subadults vs. five adults. In consecutive years many feral cat projects were executed (globally) (e.g. Lammertsma et al. 2011; Bengsen et al. 2012; Bridges et al. 2015; McGregor et al. 2015; Guttilla & Stapp 2010; Recio et al. 2011; Schmidt et al. 2007). This indicates that feral cats can be caught relatively easy. They are successfully implemented as subject in telemetry studies to track and will give insight in their spatial behaviour.

To go beyond the scientific work already executed on Schiermonnikoog and increase the body of knowledge, further research is needed. A repetition of the diet analysis is valuable but especially more work can be done on spatio-temporal analyses like home ranges, circadian activity patterns, habitat use and locomotive behaviour. So, the focus of this study is to fill that research gap and give the first insights in spatial ecological behaviour of the feral cats on Schiermonnikoog. This research aims to generate insights in which areas are used by feral cats, how they use these areas and potential reasons why they use these areas. This is valuable knowledge and a step further in understanding the ecological influence of the feral cats on Schiermonnikoog. This research is structured according to the following research questions:

- 1) What are the home ranges during different time periods?
- 2a) What are the active and inactive periods during the circadian cycle?
- 2b) What is the habitat use and how does nocturnal habitat use differs from diurnal habitat use?
- 2c) What is the relation between cumulative daily displacement and daily migration?
- 3) Which prey are ingested by the feral cats, how does this relate to previous year and what is the relation with the presence of prey in the area?

To answer the questions, a high resolution GPS tracking technique was used. Ten feral cats on Schiermonnikoog were equipped with a GPS tag to follow their movements and behaviour during the bird breeding season in 2014. Also abundance data of the presence of prey species were collected together with the prey ingested by the feral cats. This was the first time a GPS telemetry study with feral cats was executed on a Dutch Waddensea island. Although it was an exploratory research this project led to more insights in the spatial ecology of the feral cat population on Schiermonnikoog. The

findings of this study could help to find solutions to effectively solve potential negative influences by the feral cats. It can serve as input for management decisions.

This research was assessed by the Dutch Animal Ethical Experiment committee (DEC) of University of Groningen and approved by Netherlands Food and Consumer Product Safety Authority (project 6796A) for the Experiments on Animals Act. It was approved for the Flora and Fauna act under project number FF/75A/2013/047 and for the Nature Conservancy Act under reference number 01094376.

2 Method

2.1 Study area and species

Schiermonnikoog (figure 1) is one of the five populated Dutch Waddensea islands, it has approximately 1000 inhabitants (Centraal Bureau voor Statistiek 2013) and is positioned about seven kilometre of shore (53° 30'N, 6°10'E). The total natural area is roughly 3500 hectares and it has a relatively heterogeneous habitat structure, that can be divided in five main categories; salt marshes, dune valleys, former beach plain, beaches with young dunes and polders (Pranger & Tolman 2012).

The feral cats (hereafter referred to as cat) originate from house cats which are abandoned (by tourist) or escaped from local households. Presumably there is a continuing influx of new individuals and it is shown that they are capable to reproduce in the wild (Langeveld 1987). The population size in the natural area is estimated on 28 cats in 1984 (Langeveld 1987) and 50 in 2011 (op de Hoek 2012).

This research area is particularly interesting because no competing mammalian ground predators occur on the island and there is a no hunting policy since 1994 in the natural area (Berendse 2011). The densities of hares is estimated by van Wieren et al. (2006) on 72 per km². Rabbits also occur on the island, mainly in the dunes (van As 2011), but no density value could be found. Also Eurasian pygmy shrew (*Sorex minutus*), Greater white-toothed shrew (*Crocidura russula*), Common vole (hereafter referred to as vole), Brown rat (*Rattus norvegicus*), Long-tailed field mouse (*Apodemus sylvaticus*), House mouse (*Mus musculus*) and Eurasian harvest mouse (*Micromys minutus*) occur on the island (Zoogdiervereniging 2012). From these species no scientific density estimates exist either. There are 37 bird species on the island which have a Dutch Red list status (Nationaal Park Schiermonnikoog 2011) and are potentially threatened by the cat population.

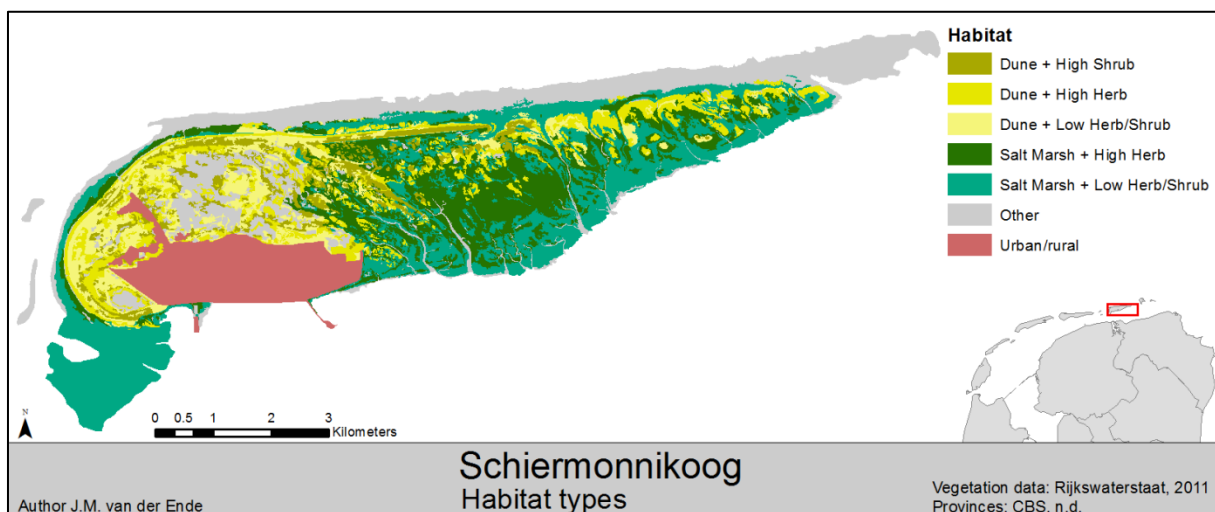


Figure 1 different habitat types in research area Schiermonnikoog

2.2 Data Collection & Analysis

2.2.1 Cat trapping and tagging

To be able to catch and tag the cats, live traps; (katzenfalle 27904; 80x29x29cm) (Drahtexpress 2013) were placed in the area in January 2014. They were covered with jute and vegetation to protect the cats from environmental influences. To optimise catching success, the trapping locations were selected as follows:

1. Where signs of cat activity (e.g. droppings, scratching) was observed.
2. Where high densities of cats were observed; according to Langeveld (1987) and Op de Hoek (2012) i.e. mainly open dunes.
3. As far as possible from the village, to prevent the capture of house cats.
4. On discrete locations, out of sight from footpaths, but still on small wild tracks, which were presumably used by the cats.

To allow the cats to become used to the traps, the doors were initially removed so the cats could walk in and out freely. Some fish and/or cat food was placed inside and around the traps and they were sprinkled with an oil-base fish scent (used in fishing as attractant for fish). This prebaiting was executed roughly each two weeks.

The catch sessions were executed in April 2014, the trapping locations are depicted in figure 2. During the catch sessions the traps were baited with sardines in oil (Lammertsma et al. 2011) and sprinkled with the fish scent. The traps were checked at least twice a day, during dusk and dawn. Once a cat was captured it was transferred to a fixation cage (kombi-falle 27906 80x29x29cm) (Drahtexpress 2013) (figure 3).

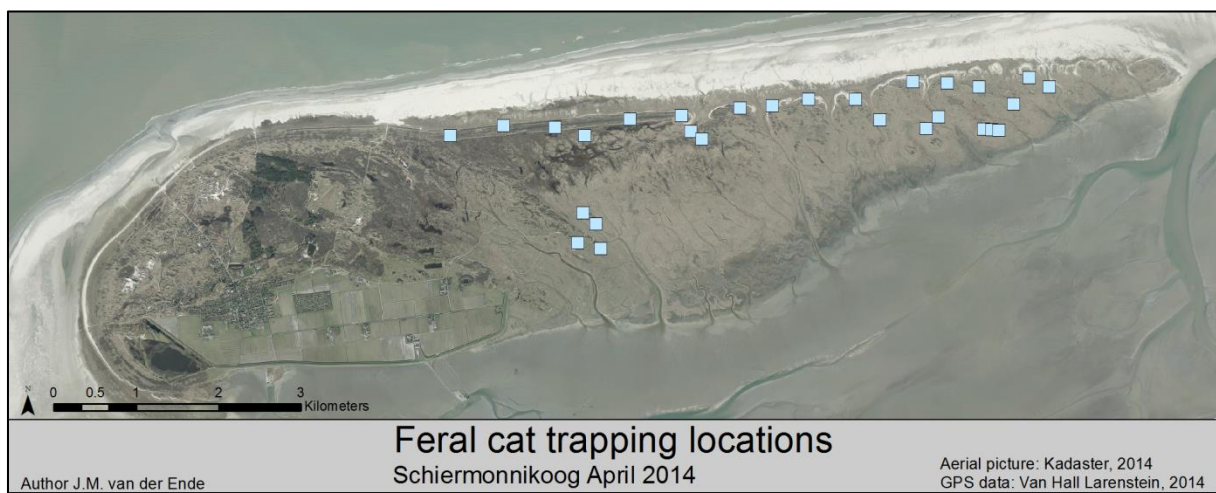


Figure 2 trapping locations April



Figure 3 cat transfer from live trap to fixation cage (photo: M. Wilson)

Once in the fixation cage the cats were restrained against the bars of the cage and intramuscularly injected with Ketamine (0.1ml/4kg) and Medetomidine (0.1ml/2kg) and Atipamezole 0.1ml/4kg as antagonist. The following data were recorded; weight (kg, using a Pesola Macro-Line Spring Scale \pm 0.3%), sex (M/F), age (juvenile, sub-adult, adult), neutered (yes/no), PIT tag (yes/no, using a PIT tag reader), reproductive status (development of testicles, mammarys, nipples or lactating), ectoparasites (yes/no), tail length (cm, basis to tip, using a tape measure), body length (cm, basis tail to tip of nose, using a tape measure), skull length (cm, tip of nose to occiput, using a calliper gauge), overall condition (visually, score 1-5), fur colour, condition of teeth; wear (visually, score 1-5), colour of gum (visually, pink, white, red, infected), missing tooth (none, #tooth, #molar), tartar (visually, score 1-5), and pictures were taken from each individual. Only cats above 2.3kg were selected so the tag would not weigh more than five percent of the cats' body weight (Gannon & Sikes 2007; Wilson et al. 1996). The GPS tag; *Collar 1C-light, 115 gram* (e-obs digital telemetry 2010) (figure 4) was attached around the neck using two UV-degradable cable wraps (figure 5). When the cat was fully recovered it was released at the trapping location.



Figure 4 used GPS tag



Figure 5 attachment of GPS tag

The tag is equipped with a GPS tag (U-Blox LEA-4S), an Ultra High Frequency (UHF) (868/916MHz bands) transmitter (to determine the location in the field from a far distance) and a tri-axial-accelerometer. To ensure sufficient data over a period of three months (breeding season) the following setup was chosen; on 04/05/14 00:00 the GPS tags started with a temporal resolution of 15 minutes and with each burst five fixes with two seconds in between. Roughly once per two weeks the cats were located (using UHF), approached and when in range (depending on habitat characteristics 200 – 1500m) the data were downloaded wirelessly from the collar to the base station.

To retrieve the tags another two sessions were executed in November and December 2014. The traps were placed on locations (figure 6) where the cats occurred most, which could be derived from the GPS data from the tags. The caught cats without a tag were released directly and the tagged cats were fixed in the squeeze cage, untagged, weighted (in the cage) and released.

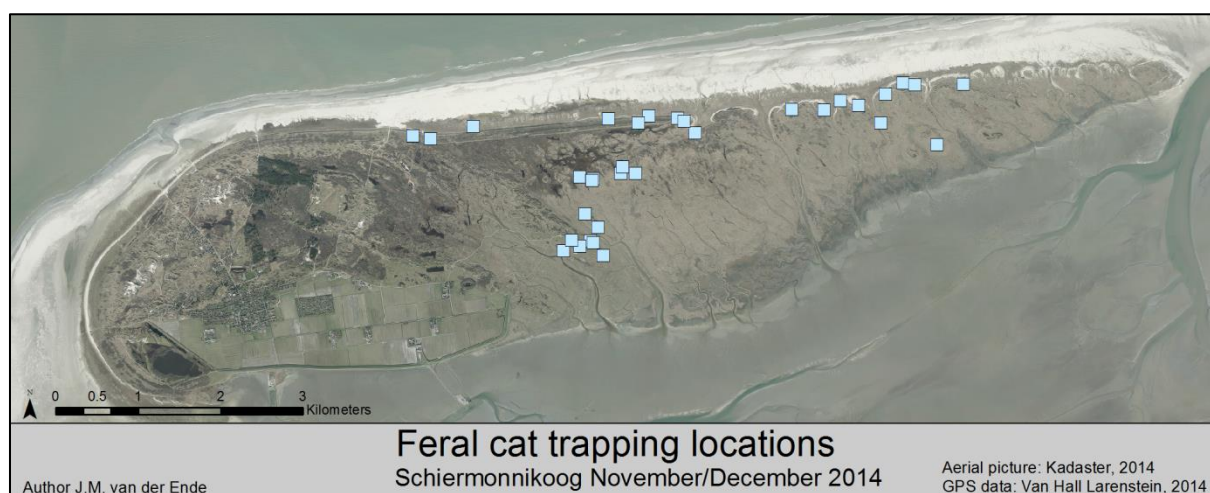


Figure 6 trapping locations November/December

2.2.2 Home ranges

The data of the GPS tags were used to calculate different home ranges (HR); diurnal (~65 fixes), nocturnal (~30 fixes), daily (max. 96 fixes per day), weekly (max. 672 fixes per week), monthly (max. 2880 fixes per month) and 3-months (max. 8640 fixes per 3-months). Several HR estimators exist and new estimators are still being developed (Walter et al. 2015). It depends on the goal of the research, sample size and type of data which estimator to use (Kie et al. 2010). Each model however has its own disadvantages, so choosing a model can be very difficult (Laver & Kelly 2008).

The Kernel HR estimator (Worton 1989) is nowadays the most popular approach to calculate HR, but it needs different input parameters from the user, which creates a multitude of possibilities (Laver & Kelly 2008). One of those and by far the most important one is the smoothing parameter, also called bandwidth or h-value. This is discussed extensively in literature and no consensus is found on which method is best (Gitzen et al. 2006).

For this research a fixed Kernel was chosen. Meaning the bandwidth is constant for all data points instead of varying (adaptive Kernel). The Plug-in bandwidth selection method (Jones et al. 1996) was used. According to Walter et al. (2011) Plug-in is appropriate for datasets with >1,000 GPS fixes which are auto-correlated and it is suitable for non-migrating animals living in patchy

environments. Walter et al. (2015) mention that if many clusters of fixes are expected Plug-in is advantageous above the biased cross validation or least-square cross validation. The Gaussian type kernel shape was used. 95% contour isopleth polygons were created, which indicate the area and surface where the cat has spent 95% of its time. The five percent which is discarded avoids Burt's 'occasional sallies' (1943) being incorporated in the HR. The Kernel HR calculations were executed using Geospatial Modelling Environment (GME) 0.7.3.0 (Beyer 2012), ArcGIS 10.2.1 (Environmental Systems Research Institute 2014) and R 3.2.1 (R Core Team 2015).

Minimum Convex Polygon (MCP) HR estimator (Mohr 1947; Hayne 1949) was also applied to compare the trend of the Kernel HR estimator. The MCP method is a non-parametric method. It is the smallest possible polygon enclosing all data points by connecting the peripheral points where the interior angles are always smaller than, or equal to 180°. Once more, to avoid Burt's (1943) 'occasional sallies', 95% MCPs were created. The five fixes furthest away from the mean centre of all fixes were rejected before execution of the MCP analysis. 10% MCP HR were also created. This method is highly criticized due to its weaknesses (Harris et al. 1990; White & Garrott 1990) and should not be used according to Laver and Kelly (2008). However, it is still widely implemented and therefore used here also to allow comparison with other studies. The 100% MCP HR were created using GME 0.7.3.0 (Beyer 2012) and because GME had no option for the 95% MCP HR these were calculated using Python 2.7.5 (Python Software Foundation 2013) (appendix I) and ArcGIS 10.2.1 (Environmental Systems Research Institute 2014).

To test the difference between mean nocturnal and mean diurnal HR sizes a boxplot was created and the difference tested with a Wilcoxon signed-rank test because the data were not normally distributed and has repeated measures. The sex and age-specific differences in HR sizes were tested using Mann-Whitney U tests for the 3-Month HR only. The statistical analyses were executed using IBM SPSS Statistics 22.0 (IBM Corporation 2013).

2.2.3 Circadian activity pattern

The data of the GPS tag were used to calculate the daily activity pattern. Therefore the displacement between the fixes (15 minutes) was calculated using the LatLon 1.0.2 package (Del Raye 2014) in Python 2.7.5 (Python Software Foundation 2013) (appendix II row 249-259). Each day was divided in three periods 1) Early morning: sunrise – two hours after sunrise; 2) day: two hours after sunrise – sunset; 3) night: sundown - sunrise (appendix II row 138-170). The local sunrise and sunset times were used (Redwoods 2014).

To find if a period had an effect on the average displacement per 15 minutes a Linear Mixed Model (LMM) was used. CatID was used as subject variable, mean displacement per 15 minutes as dependent variable and period, age, sex and the all interactions between these variables as fixed factors. Variables and interactions were in- or excluded until the lowest Hurvich and Tsai's Criterion (AICC) was reached, which indicates when the model performs best. The LMM was performed using IBM SPSS Statistics 22.0 (IBM Corporation 2013).

2.2.4 Habitat use

The GPS fixes of the cats were used to identify the usage of different habitats. Habitat is defined by Hall et al. (1997, p.175) “as the resources and conditions present in an area that produce occupancy – including survival and reproduction – by a given organism”. Because the habitat use of the cats is largely driven by the abundance of prey (Recio & Seddon 2013) it was assumed that prey abundance on Schiermonnikoog was correlated with vegetation structure. To classify the habitat, vegetation zonation was separated first in dune or salt marsh. These were further separated in the different vegetation structures per zonation (Pranger & Tolman 2012). Similar vegetation structures were grouped and vegetation structures that were hardly present or bare were reclassified to ‘Other’ (table 1). This resulted in following habitats: 1) Salt Marsh + High Herb; 2) Salt Marsh + Low Herb/Shrub; 3) Dune + High Shrub; 4) Dune + High Herb; 5) Dune + Low Herb/Shrub; 6) Other (figure 1). To assign habitat to the GPS fixes and union the vegetation structure and vegetation zonation, ArcGIS 10.2.1 (Environmental Systems Research Institute 2014) was used.

If the mean displacement per 15 minutes for a period did not significantly differ from another (as explained in 2.2.3) these periods were merged. IBM SPSS Statistics 22.0 (IBM Corporation 2013) was then used to extract a random sample (N=600) from each period per cat to make the data quasi-independent. A Chi-Square test per cat was used to find the difference in habitat use between the periods.

Table 1 habitat classification method based on Pranger & Tolman (2012)

| Vegetation Zonation | Vegetation Structure | Habitat | Vegetation Zonation | Vegetation Structure | Habitat |
|---------------------|----------------------|-----------------------------|---------------------|----------------------|-----------------------|
| Salt Marsh | Herb 30-100 cm | Salt Marsh + High Herb | Dune | Shrub > 50 cm | Dune + High Shrub |
| Salt Marsh | Herb < 30 cm | Salt Marsh + Low Herb/Shrub | Dune | Herb 30-100 cm | Dune + High Herb |
| Salt Marsh | Shrub < 50 cm | Salt Marsh + Low Herb/Shrub | Dune | Herb < 30 cm | Dune + Low Herb/Shrub |
| Salt Marsh | Bare | Other | Dune | Shrub < 50 cm | Dune + Low Herb/Shrub |
| Salt Marsh | Herb >100 cm | Other | Dune | Bare | Other |
| Salt Marsh | Shrub > 50 cm | Other | Dune | Herb >100 cm | Other |
| | | | Other | - | Other |

2.2.5 Migration vs. displacement

To compare the migration behaviour with displacement behaviour first the mean centre (figure 7) of the fixes of each day was calculated per cat. The distances between the consecutive mean centres were regarded as daily migration distances and calculated using Python 2.7.5 (Python Software Foundation 2013) (appendix III) and ArcGIS 10.2.1 (Environmental Systems Research Institute 2014). The average of these distances over the whole study period per cat was regarded the mean daily migration.

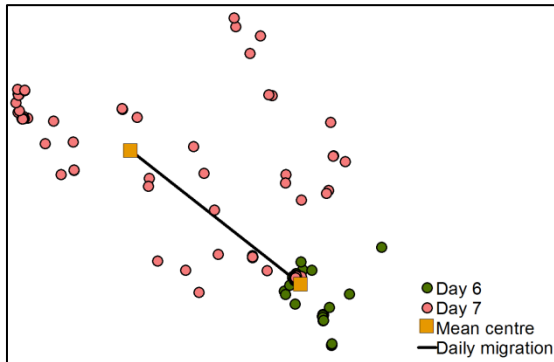


Figure 7 example of daily migration calculation

To calculate the cumulative displacement all distances, which were calculated as explained in paragraph 2.2.3, were summed per day. The summations were averaged for the whole period for each cat and was regarded the mean cumulative daily displacement. In paragraph 2.3 is explained that fixes with accuracy above 40m are discarded, but for this specific analysis these were still included. The two variables were plotted in a scatterplot to distinguish different cat behaviours.

2.2.6 Prey ingested

Fresh scats were collected haphazardly (found by chance without systematic approach) during field visits from March 2014 till December 2014. The distribution of the collected scats is illustrated in figure 8. It also shows the scat area for the analysis of prey presence (paragraph 2.2.7). After the scats were dried in a stove, they were analysed following the method from Op de Hoek (2012), Maris (2013) and Husson (1962). The prey remains were identified and counted in a lab situation. In addition to previous years it was tried to separate the hares from rabbits by identifying the hairs based on the patterns of the cuticular scales. Per scat five overhairs were cleaned, placed in a layer of wet transparent nail polish on a microscopic slide, dried for a few seconds and pulled off. The pattern of the hair scales became visible in the medium using a magnification of 400x and could be identified (Teerink 1991). Because the patterns of hare and rabbit are quite similar it was too difficult to distinguish a species in some occasions. These were identified as *Leporidae* species.

The results were expressed in frequency of occurrence (F) and percent relative frequency of occurrence (R) calculated using the following formula:

$$R_i = F_i / N * 100$$

with

R = Relative frequency in %

F = sum of individual prey per species found in all scats

i = prey species

N = sum of prey individuals of all species found in all scats

The results of 2014 were compared with previous years using a table and a bar graph.



Figure 8 distribution of the collected scats

So far previous research on Schiermonnikoog only focussed on frequency of prey in the scats. but there are two shortcomings using this method. For small mammals it is possible to count the number of individuals per scat using the jaws. For *Leporidae* species however it was, until now, assumed that one scat contained one prey individual. It is possible, that several scats can contain one individual prey. For example if a cat eats from the same big prey for a longer period or several cats eat from the same carcass. To circumvent this bias a method was used to obtain a more conservative number of *Leporidae* species eaten. From the scats collected in 2014 only those were used when the time between scats found was more than one month, except when the scats were outlying more than 6km (the maximum observed length between the outermost locations of a cat during a month (personal observation)). It was assumed that the scats that remained, represent one prey and was used as input for the volume calculation explained hereafter. Secondly the different prey species can differ enormously in body mass. For example a hare of four kilo has the same body mass as 160 voles of 25gm, so the energetic value of one hare is of course much higher than one vole. Hence the frequency of occurrence (F) was recalculated into volume of prey. Therefor the body weights of each prey species was needed. For the small mammals this was obtained from the results of the trapping session (see next paragraph), the other mammals from The Dutch Mammal Society (n.d.) and the birds from The Wildlife Trusts (n.d.). If a body size range was given, the median was used as input for the calculation for the smaller animals (<200gm) and the minimum for larger animals. Because bird species could not be distinguished during the scat analysis, one universal body mass had to be decided per size class (small; medium; large). Therefor the mean of the small (<100gm), medium (100 - 600gm) and large (>600gm) ground breeding birds present in the area was used (table 2). The results were expressed as relative ingested volume of prey (V) and calculated using the following formula:

$$V_i = M_i * F_i / T * 100$$

with

V = relative ingested volume of prey in %

M = body mass

F = sum of individual prey per species found in all scats

T = sum of volume of all species found in all scats

This resulted in the volume of prey eaten by the cats and was compared to the prey present in the scat area as explained in the following paragraph.

2.2.7 Prey presence

From 15 July until 1 August 2014 prey density estimates were executed on Schiermonnikoog. Hare and rabbit densities were estimated by pellet counts in randomly placed circular plots of 3.14m². The surface of the plot was too small what resulted in many zero counts. It was also hard to distinguish hare and rabbit pellets for the observers, so identification was not 100% certain. The disintegration time of the pellets was also observed to be different between the habitats, but not measured. So the chosen method proved not solid and the results were discarded from analysis. No density estimate from rabbits could be made because much is still unknown about the population demographics on Schiermonnikoog (van As 2011). For the hares on the other hand, van Wieren et al (2006) calculated the density on Schiermonnikoog and found an average of 71.5 hare/km² between 1996 and 2003. Their study area was partly overlapping the scat area from this research and is assumed to be a representative sample.

The small mammal density was estimated using the trapping method of Koelman (2007) and Gurnell & Flowerdew (2006) by placing 55 live traps (Longworth) on different line transects. Each transect was placed randomly in the research area (figure 9) and consisted out of 11 traps placed ten meter apart. The traps were filled with hay, to protect the caught mice from low temperatures, and baited with peanut butter, oats, carrot, apple, mealworms and maggots. A prebaiting time of 36 hours was used and after 60 hours of trapping the transects were relocated. This was done for four times, multiplied with five transects, makes 20 different locations in the area.

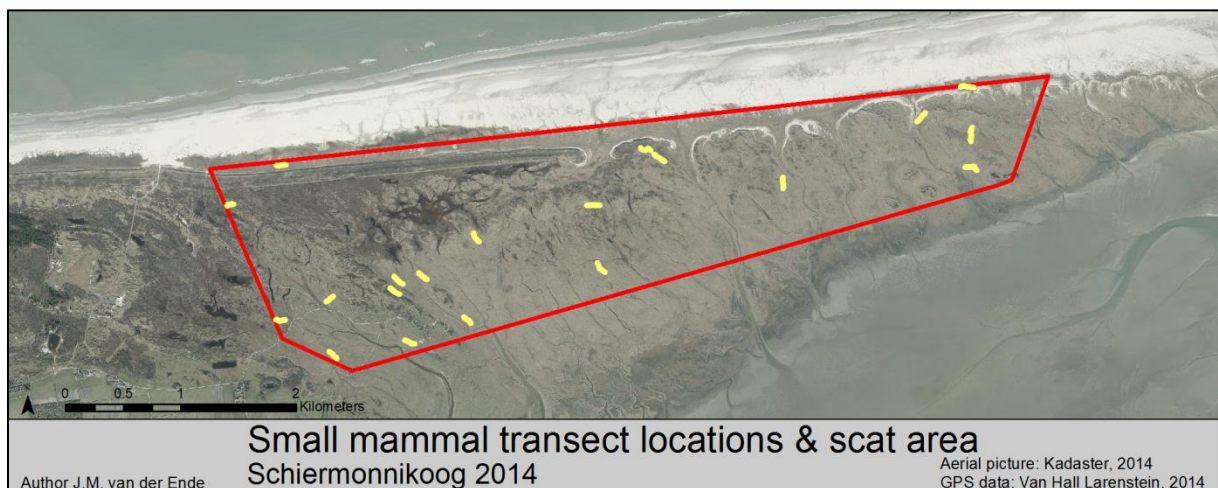


Figure 9 mice trapping transect distribution in the research area

The traps were checked twice a day. Caught animals were identified, sexed, weighted and marked (by cutting a piece of fur) for recognition in case it was caught again. The density estimation was calculated as follows:

$$D_i = N_i / (A * n)$$

with

D = density

i = prey species

N = number of caught individuals

A = surface of a transect

n = number of transects

The total number of unique individuals caught was used, so marked animals were counted only once. It was assumed that the traps attract mice within a radius of five meter, thus the surface of one transect was $110 * 10 = 1,110\text{m}^2$ (Gurnell & Flowerdew 2006).

The bird density was calculated based on the results from Klemann & Kleefstra (2012). They assessed the breeding bird numbers in 2012 which were recorded for the whole island using the Dutch BMP-A method (van Dijk & Boele 2011). The ground breeding birds in the scat area (figure 8) were extracted from the dataset but not all species were taken into consideration for the presence analysis. Some exceptions were made; Greylag goose (*Anser anser*), Egyptian goose (*Alopochen aegyptiaca*), and gull (*Larus sp.*) colonies were assumed to be unavailable for the cats because of their aggressive behaviour during breeding season towards predators (personal observations). Species occurring in very low frequency (<5 territory) were also left out, such as Short-eared Owl (*Asio flammeus*), Black-tailed Godwit (*Limosa limosa*), Spoonbill (*Platalea leucorodia*) and Lapwing (*Vanellus vanellus*). Species used in the calculation are shown in table 2.

Table 2 input for prey volume calculation

| English | Dutch | Scientific | Weight used (gm) | Sizeclass |
|-----------------------------|---------------|------------------------------|------------------|-----------|
| Pheasant | Fazant | <i>Phasianus colchicus</i> | 975 | Large |
| Mallard | Wilde Eend | <i>Anas platyrhynchos</i> | 970 | Large |
| Shelduck | Bergeend | <i>Tadorna tadorna</i> | 900 | Large |
| Curlew | Wulp | <i>Numenius arquata</i> | 770 | Large |
| Oystercatcher | Scholekster | <i>Haematopus ostralegus</i> | 540 | Medium |
| Redshank | Tureluur | <i>Tringa totanus</i> | 110 | Medium |
| Skylark | Veldleeuwerik | <i>Alauda arvensis</i> | 38 | Small |
| Meadow pipit | Graspieper | <i>Anthus pratensis</i> | 19 | Small |
| Common whitethroat | Grasmus | <i>Sylvia communis</i> | 16 | Small |
| Hare | Haas | <i>Lepus europaeus</i> | 3000 | |
| Rabbit | Konijn | <i>Oryctolagus cuniculus</i> | 1200 | |
| Lagomorph sp | | <i>Leporidae</i> | 1200 | |
| Brown rat | Bruine Rat | <i>Rattus norvegicus</i> | 200 | |
| Common Vole | Veldmuis | <i>Microtus arvalis</i> | 25 | |
| Long-tailed field mouse | Bosmuis | <i>Apodemus sylvaticus</i> | 22 | |
| Greater white-toothed shrew | Huisspitsmuis | <i>Crocidura russula</i> | 10 | |

For all prey groups (hares, birds and small mammals) a very rough abundance estimation was made for the scat area by multiplying the density with the area size. For the bird data the densities of territories was calculated so this was multiplied by two (pair of birds) first. Once the abundance of each prey was known it was multiplied with the weight per species which result is expressed as the relative volume of prey present in the scat area (P). The following formula was used for the mammal species:

$$P_i = D_i * A * M_i / T * 100$$

with

P = relative prey volume present in %

i = prey species

D = density

A = surface scat area

M = body mass

T = sum of volume of all species in scat area

For the birds the following formula was used:

$$P_i = D_i * 2 * A * M_i / T * 100$$

This result was compared with the volume of prey eaten as explained in the previous paragraph.

2.3 Data Preparation

To increase the spatial accuracy of the observations the data were prepared and processed using Microsoft Excel 2010 and Python 2.7.5 (Python Software Foundation 2013). These external Python site packages were required: LatLon 1.0.2 (Del Raye 2014); Fiona 1.5.1 (Gillies 2014a); Shapely 1.5.7 (Gillies 2014b) & ArcPy 10.2.1 (Environmental Systems Research Institute 2014). The following actions were taken.

1. Only the fifth fix (from a burst) was used because this had the best horizontal accuracy. If the fifth burst was not successful, a previous fix in the burst was used instead. In case all fixes from a burst were unsuccessful the fix was deleted. From here onwards each fix had a temporal resolution of 15 minutes or more.
2. If a fix was unsuccessful but the previous and the following fix were successful, it was recalculated using linear interpolation (appendix II row 217 – 229).
3. Before application, the tags were placed on different locations in the study area. They totally recorded 1,020 fixes during approximately 12 hours and the average distance from each fix to the exact location of the tag (recorded with a Garmin GPSmap 64 handheld device) was calculated. The measured accuracy was plotted (figure 10), against the given horizontal accuracy by the tag (e-obs digital telemetry 2013). After visual inspection it was decided that the fixes from the entire GPS-dataset with a given accuracy above 40m were excluded from analysis (2.4% of the data). Also the average accuracy could be calculated what was 16.9m.
4. The turning angle and displacement was calculated, spikes were identified and smoothed using the following criteria; tuning angle $>160^\circ$ and displacement $<16.9\text{m}$ (figure 11) (appendix II row 249-364). These decisions were based on the following assumption: if a successive fix had a distance of more than the average accuracy (16.9m), it was assumed that this was not caused by the tag but that the cat really walked that distance.
5. The coordinates in the .csv dataset were transformed to geographical point locations and exported to a shapefile for further analysis (appendix II row 367-411).

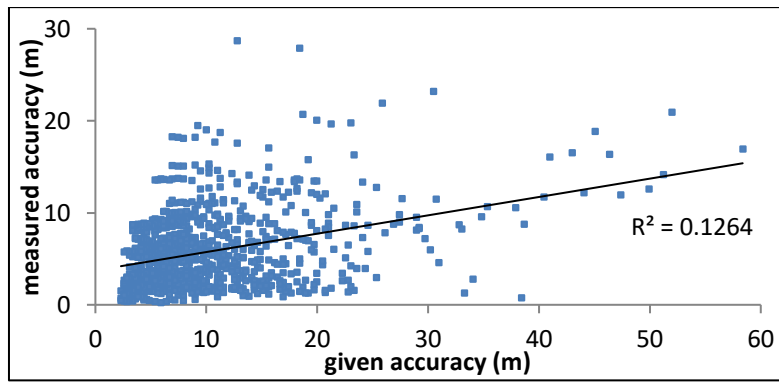


Figure 10 the measured accuracy (using Garmin GPSMap62 handheld device) versus the given accuracy by the tag. 1020 fixes were collected by placing the tag stationary in the field

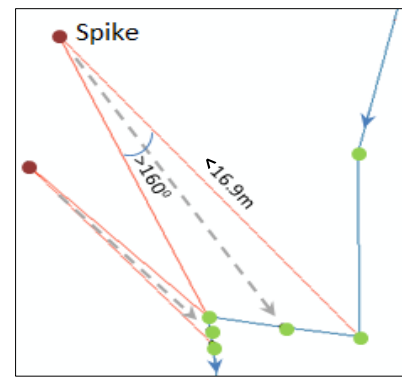


Figure 11 example of spike smoothing

3 Results

3.1 Trapping

During the April sessions, ten cats (table 3 & appendix IV) were caught during 680 trapping hours (total trapping time of all traps together). This roughly means one cat per trap per three days. Five males and five females were caught and the age class (adult / subadult) was also equally divided. One tag was internally damaged and did not function correctly, another was unable to be located after 31/07/14, a third was drained on 24/08/14 and the remaining were turned off on 16/09/14. The tag from cat 7 was for 11 days in what appeared to be a reset mode, in which it collected exceptionally inaccurate data and had to be discarded.

Table 3 overview of caught cats and data collected by the tags

| Cat | Sex | Age | Weight kg | | GPS started | GPS stopped | # Total fixes | Remark |
|-------|-----|-----|-----------|-----------|---------------|----------------|---------------|----------------------------|
| | | | 1st catch | 2nd catch | | | | |
| 0 | M | Ad | 4.6 | 6.2 | 4-05-14 22:13 | - | - | Tag damaged |
| 1 | F | Ad | 3.3 | 3.3 | 4-05-14 0:00 | 24-08-14 23:45 | 10848 | Presumably pregnant |
| 2 | M | Sub | 2.6 | - | 4-05-14 0:00 | 16-09-14 23:45 | 13056 | |
| 3 | M | Sub | 2.6 | - | 4-05-14 0:00 | 16-09-14 23:45 | 13056 | |
| 4 | F | Sub | 2.6 | 2.7 | 4-05-14 0:00 | 16-09-14 23:45 | 13056 | |
| 5 | F | Sub | 2.4 | - | 4-05-14 0:00 | 16-09-14 23:45 | 13056 | |
| 6 | M | Sub | 3.0 | - | 4-05-14 0:00 | 31-07-14 23:45 | 8544 | |
| 7 | F | Ad | 3.6 | 3.9 | 4-05-14 0:00 | 16-09-14 23:45 | 13056 | Mating observed with cat 9 |
| 8 | F | Ad | 2.8 | 3.4 | 4-05-14 0:00 | 16-09-14 23:45 | 13056 | Pregnant / Kittens found |
| 9 | M | Ad | 4.1 | - | 4-05-14 0:00 | 16-09-14 23:45 | 13056 | |
| Total | | | | | | | 110784 | |

During the November & December trapping sessions 24 catches were successful during 1,550 trapping hours. These led to 16 different individuals whereof five were tagged. After re-catch all tagged animals, except for cat 1, had gained weight ($M=0.52\text{kg}$, range=0.0-1.6kg) (table 3).

Figure 12 gives an overview of the trapping locations and successful catches from both periods. In the dunes ('Kobbeduinen' and 'Stuifdijk') rats (*Rattus norvegicus*) were captured also, but only during the night. There was no other bycatch. The nine functioning tags collected 110,784 fixes in total. After data preparation 108,512 suitable fixes remained for the whole period and for the study period (May, June & July) 76,896 suitable fixes were used.

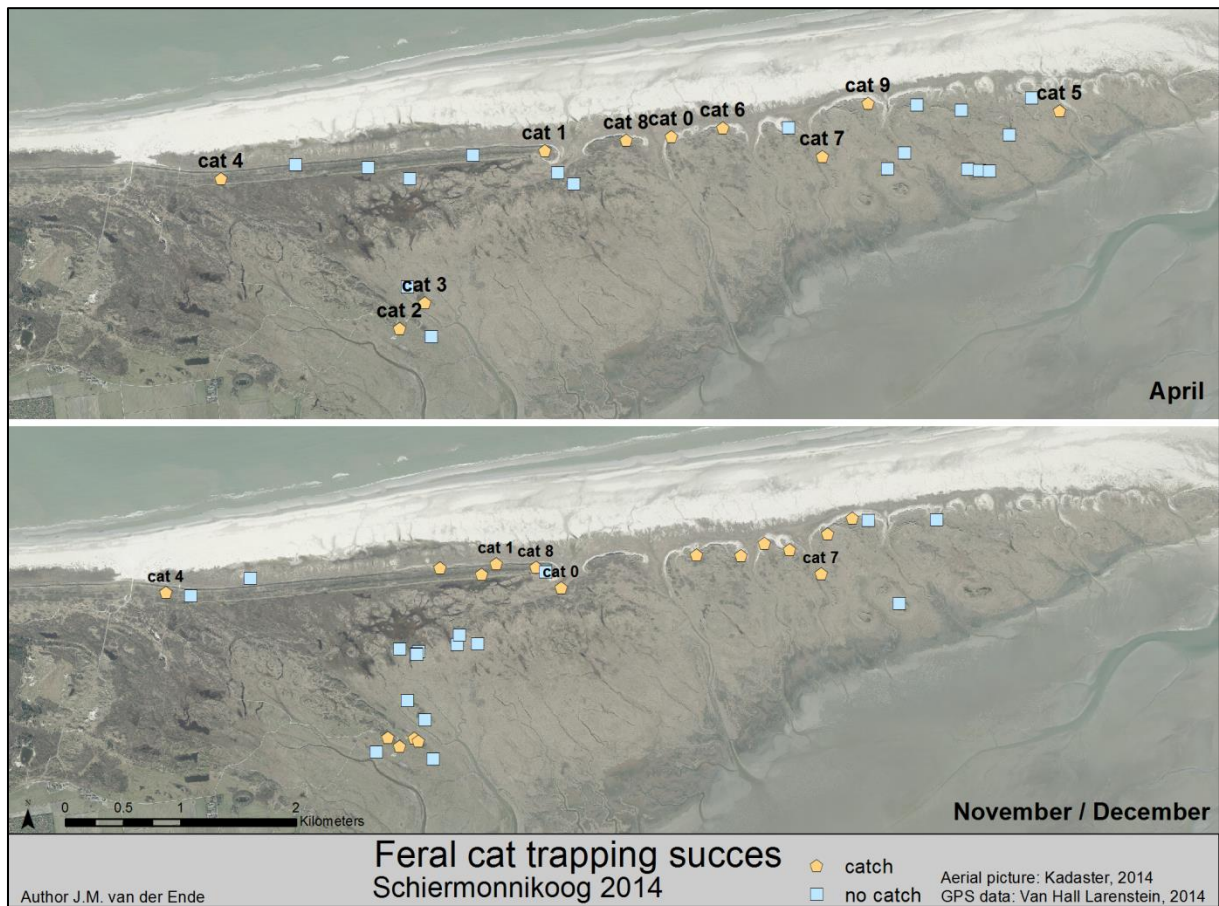


Figure 12 locations where cats were, or were not, captured during the different trapping sessions

3.2 Home ranges

For each of the three HR methods 2,505 HR sizes were calculated. These were 782, 783, 790, 114, 27, and 9, for diurnal, nocturnal, daily, weekly, monthly and 3-months respectively. Some examples are visualised in figure 13. The difference of both the 95% HR methods are shown. It is notable that the Kernel density estimator did not discard five percent of the data when the sample sizes were small: diurnal, nocturnal and daily. It seems a relatively large overestimation of the real HR. When the sample sizes got bigger (weekly and longer) it did discard five percent of the data as it was supposed to do.

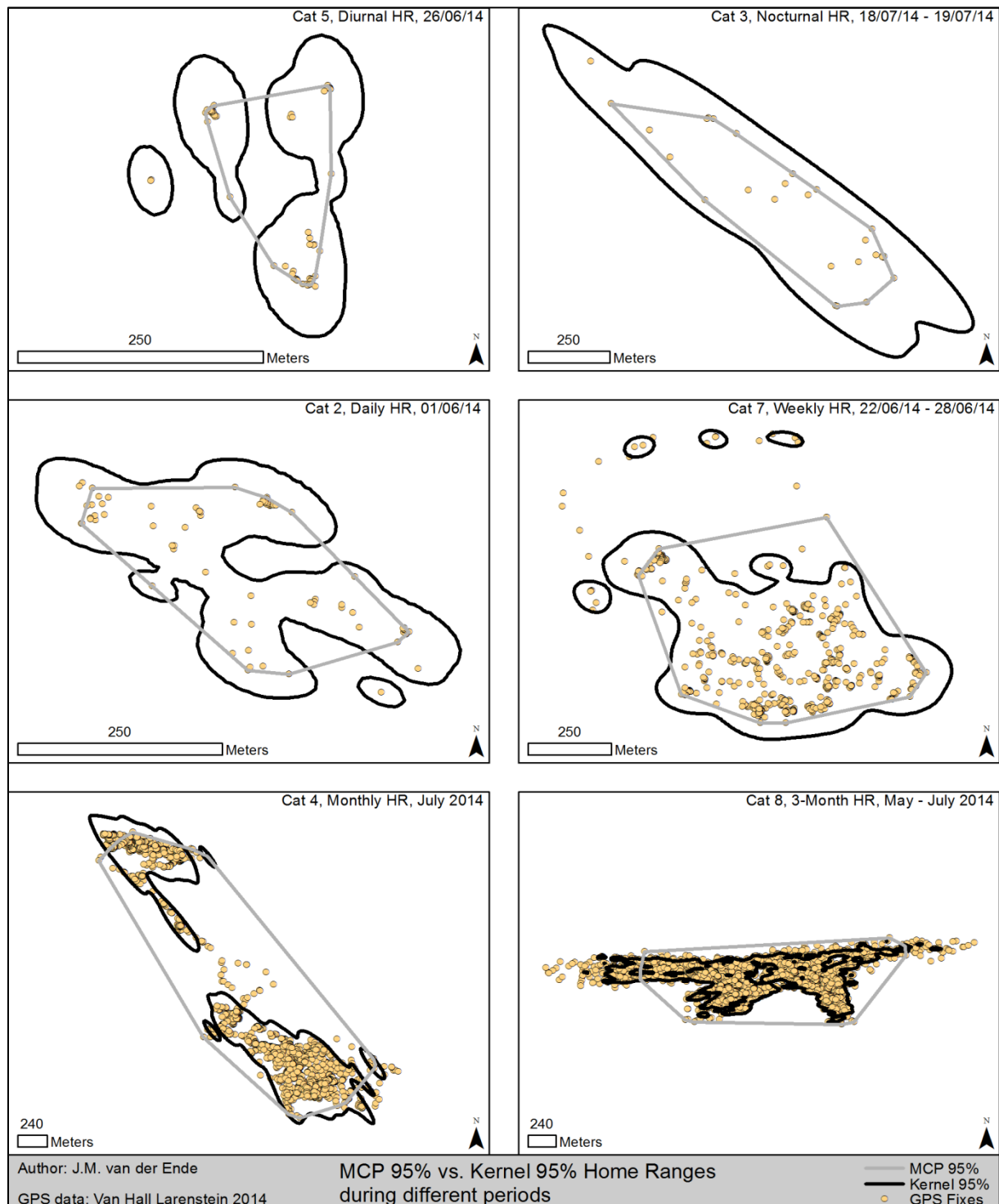


Figure 13 examples of MCP 95% and Kernel 95% HR estimations

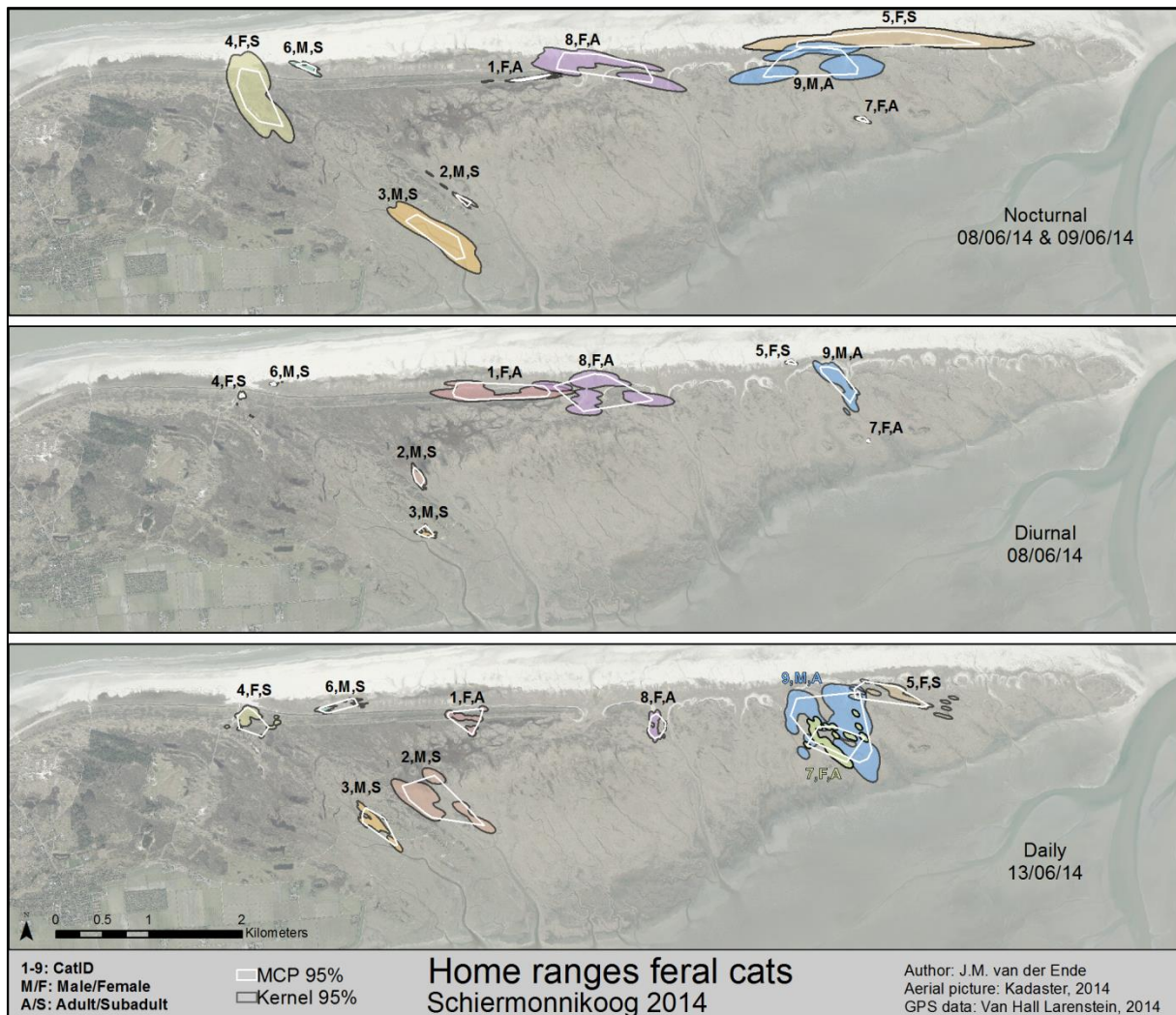


Figure 14 different temporal Kernel 95% and MCP 95% home ranges of feral cats (n=9) on Schiermonnikoog

In figure 14 and figure 15 more examples of MCP 95% and Kernel 95% HR are visualised for all cats in the research area. There are some notable things to point out. First, it can be seen again that the Kernel density estimator overestimated the nocturnal HR. Secondly, cat 1 and 8 had bigger diurnal HR than the other cats on 08/06/15, but on average cat 9 had the biggest diurnal HR (22ha Kernel 95%) (table 4). Thirdly, the HR of cat 7 (female) and 9 (male) overlapped each other more compared to other cats, even full overlap in three months' time. These cats were also observed mating in May. Cat 2 and 3 (both males) on the other hand, hardly overlapped although they lived relatively close to each other. Fourthly, the HR expansion of cat 4 is interesting to follow. It was observed she did some sallies to the south. In three months' time she had a vast expansion of her HR in south-south-east direction (also see figure 18), close to cat 3, with negligible overlap. Finally the widest Kernel 95% 3-month HR was from male cat 6 (6.8km) which had a very elongated HR overlapping at least three other cats. Additional HR are depicted in figure 16, figure 17 (MCP 95% vs. MCP 100%), figure 18 and figure 19 (May, June & July HR separately).

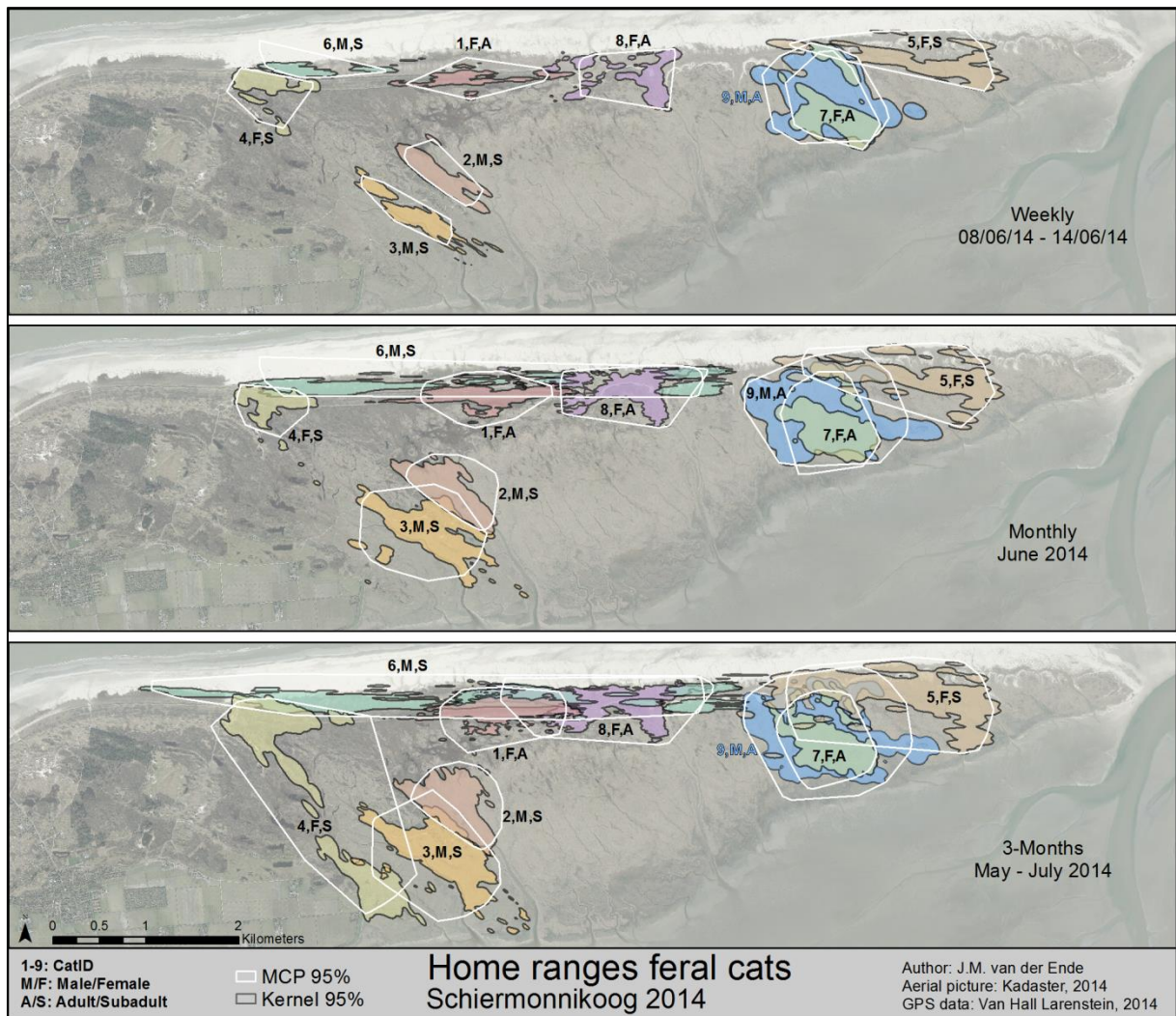


Figure 15 different temporal Kernel 95% and MCP 95% home ranges of feral cats (n=9) on Schiermonnikoog

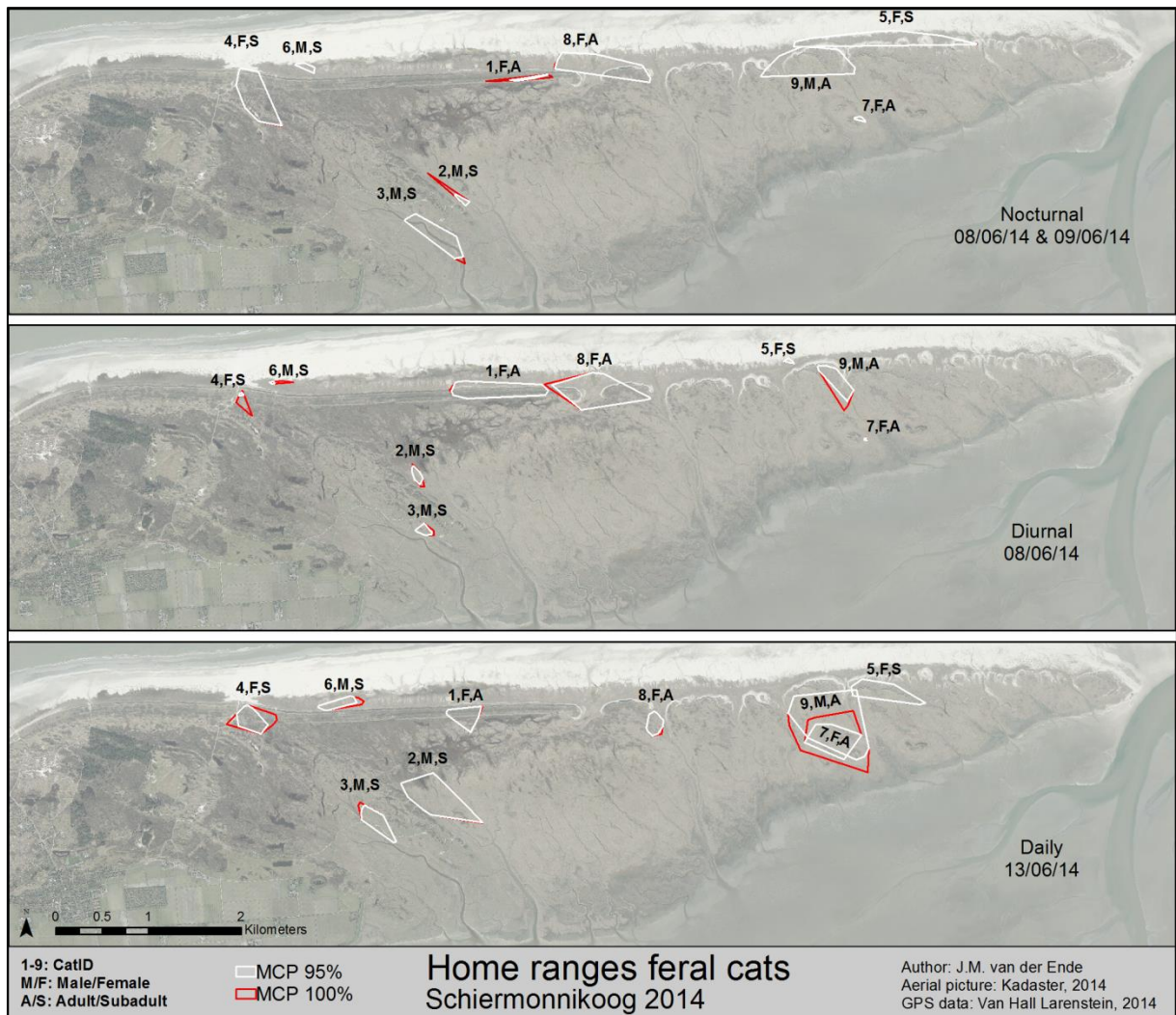


Figure 16 different temporal MCP 95% and MCP 100% home ranges of feral cats (n=9) on Schiermonnikoog

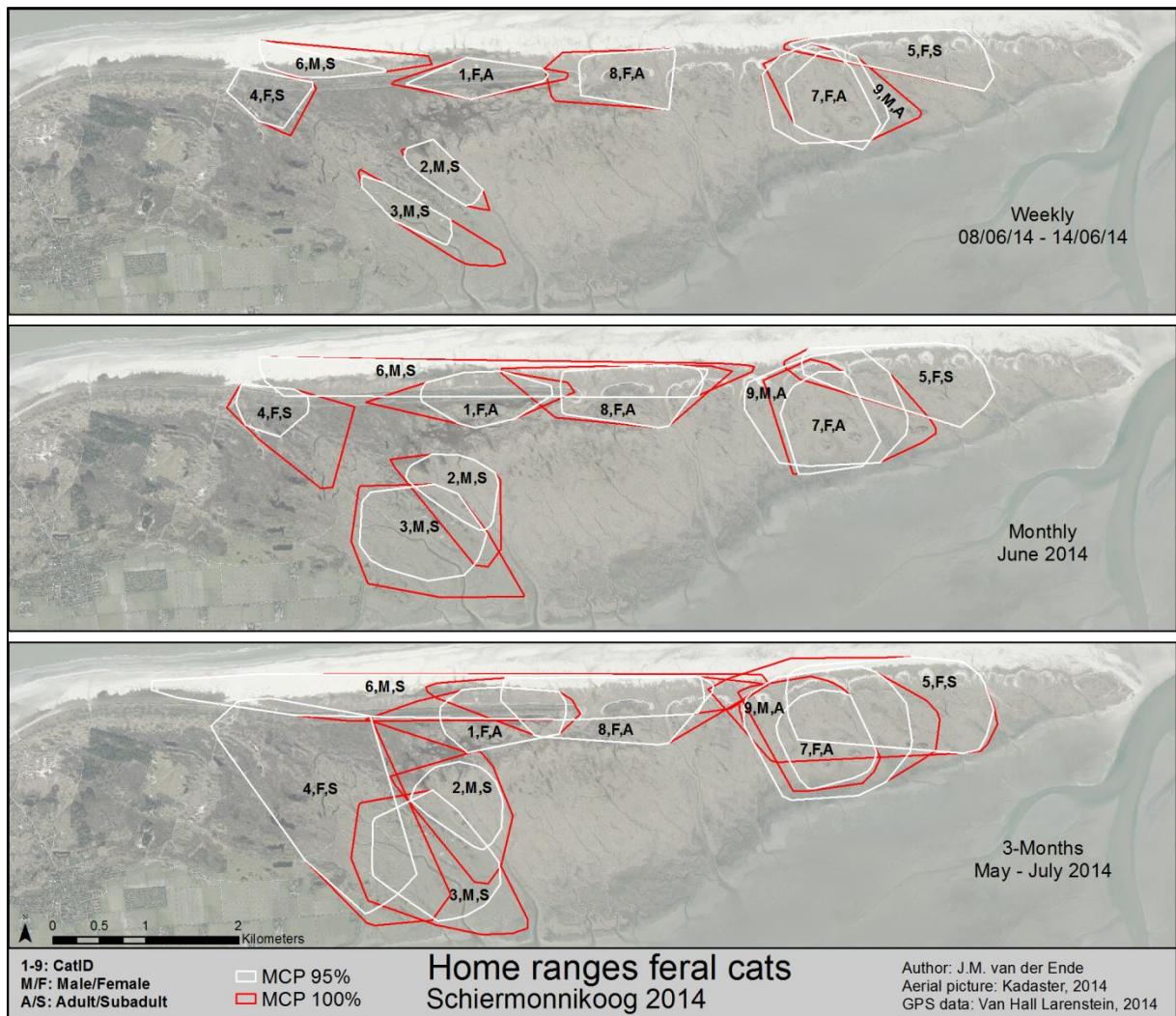


Figure 17 different temporal MCP 95% and MCP 100% home ranges of feral cats (n=9) on Schiermonnikoog

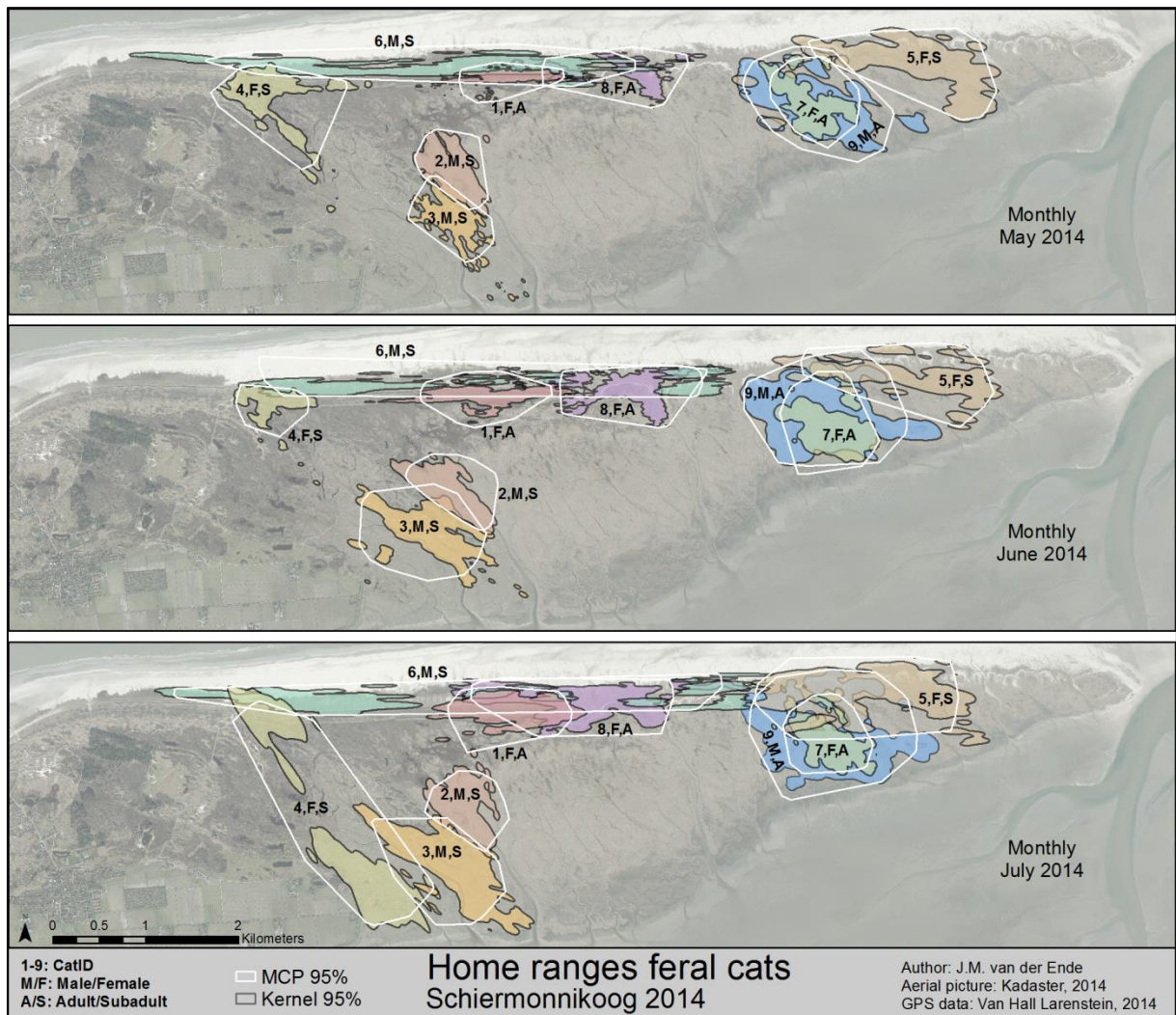


Figure 18 monthly Kernel 95% and MCP 95% home ranges of feral cats (n=9) during different months on Schiermonnikoog

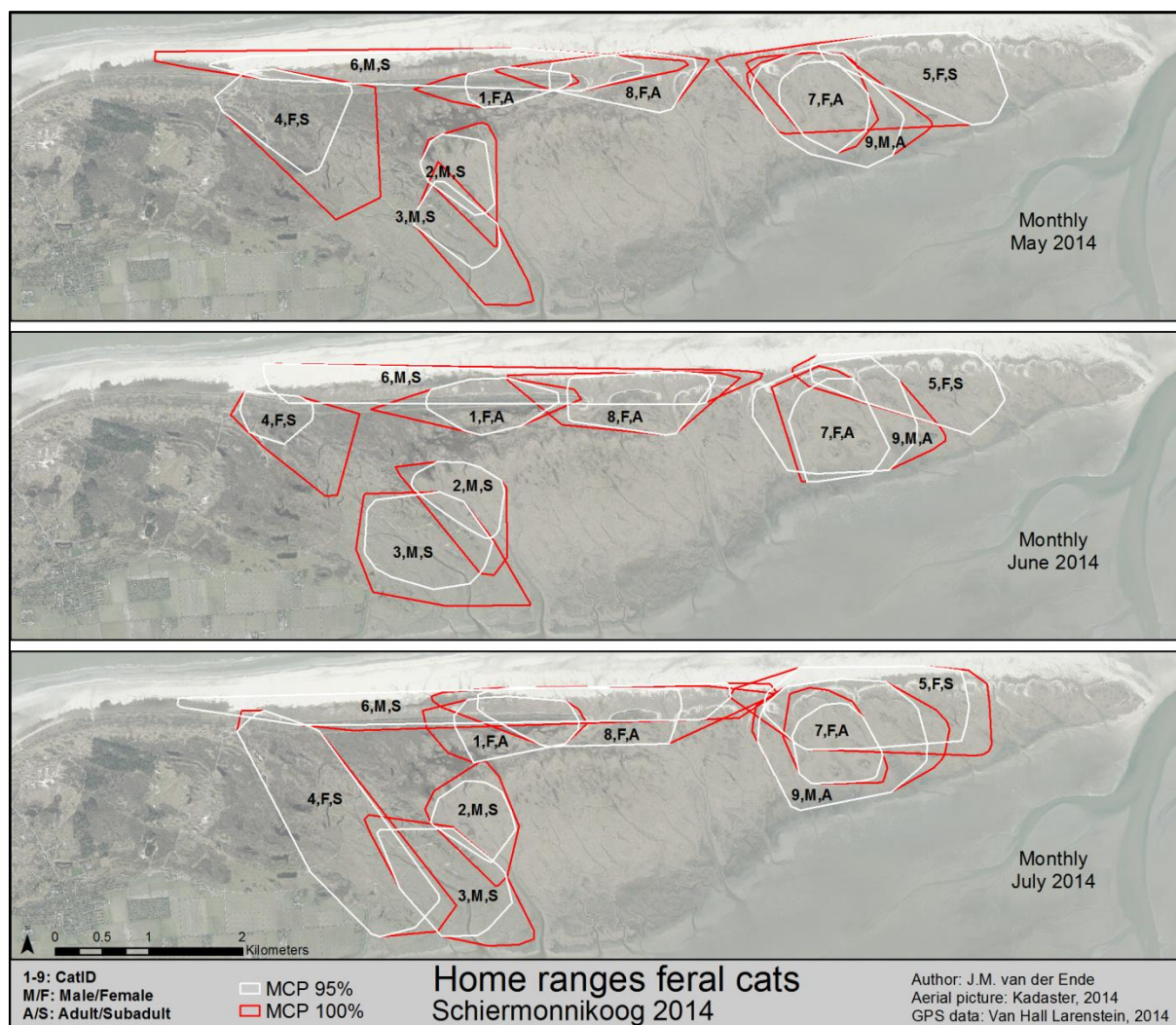


Figure 19 monthly MCP 95% and MCP 100% home ranges of feral cats (n=9) during different months on Schiermonnikoog

In table 4 the average HR sizes overall, per sex, per age class and per cat are presented. For all three HR methods the males had larger HR than females, but with a statistically non-significant difference (Mann–Whitney $U=7.0-10.0$, $n_1=5$ $n_2=4$, $p=0.462-1.000$ two-tailed). For adult and subadult the same was true, except for the monthly and 3-month HR. The subadults had the same HR sizes or even bigger, but yet again, not significant (Mann–Whitney $U=4.0-7.0$, $n_1=5$ $n_2=4$, $p=0.142-0.462$ two-tailed). The biggest Kernel 95% 3-month HR was from the big male cat 9 (140 ha), followed by female cat 5 (110 ha). The smallest was from female cat 1 (37 ha), followed by male cat 2 (48 ha). For the MCP 95% method the female cat 4 had the largest HR (289 ha), more than two times the size of her Kernel 95% HR (111 ha). Male cat 2 had the smallest MCP 95% HR (62 ha).

Table 4 average HR size for different cats, sexes, ages and periods. Using Kernel 95%, MCP 95% and MCP 100% density estimator methods. *M*= average; *n*=sample size; *SD*=Standard Deviation.

| values in ha | | Diurnal | | | Nocturnal | | | Day | | | Week | | | Month | | | 3-Month | | |
|--------------|----------|---------|----|----|-----------|----|----|-----|----|----|------|----|----|-------|---|-----|---------|---|-----|
| Cat,sex,age | | M | n | SD | M | n | SD | M | n | SD | M | n | SD | M | n | SD | M | n | SD |
| Kernel 95% | 1,F,A | 8 | 88 | 7 | 7 | 88 | 8 | 11 | 89 | 8 | 23 | 13 | 11 | 31 | 3 | 16 | 37 | 1 | |
| | 2,M,S | 8 | 88 | 7 | 7 | 88 | 11 | 12 | 89 | 9 | 29 | 13 | 8 | 41 | 3 | 3 | 48 | 1 | |
| | 3,M,S | 5 | 88 | 4 | 23 | 88 | 24 | 17 | 89 | 13 | 41 | 13 | 20 | 62 | 3 | 25 | 72 | 1 | |
| | 4,F,S | 5 | 88 | 5 | 16 | 88 | 25 | 12 | 89 | 13 | 36 | 13 | 21 | 55 | 3 | 40 | 92 | 1 | |
| | 5,F,S | 2 | 88 | 3 | 35 | 88 | 33 | 10 | 89 | 9 | 58 | 13 | 29 | 90 | 3 | 18 | 111 | 1 | |
| | 6,M,S | 1 | 88 | 1 | 11 | 88 | 14 | 5 | 89 | 6 | 35 | 13 | 32 | 73 | 3 | 17 | 99 | 1 | |
| | 7,F,A | 2 | 78 | 3 | 15 | 79 | 19 | 8 | 78 | 7 | 31 | 10 | 13 | 48 | 3 | 7 | 59 | 1 | |
| | 8,F,A | 15 | 88 | 18 | 14 | 88 | 18 | 18 | 89 | 21 | 35 | 13 | 21 | 51 | 3 | 27 | 69 | 1 | |
| | 9,M,A | 22 | 88 | 20 | 48 | 88 | 48 | 43 | 89 | 29 | 102 | 13 | 28 | 125 | 3 | 23 | 140 | 1 | |
| | Male | 9 | 4 | 9 | 22 | 4 | 19 | 19 | 4 | 17 | 52 | 4 | 34 | 75 | 4 | 36 | 90 | 4 | 39 |
| | Female | 6 | 5 | 5 | 17 | 5 | 10 | 12 | 5 | 4 | 36 | 5 | 13 | 55 | 5 | 21 | 74 | 5 | 29 |
| | Adult | 12 | 4 | 8 | 21 | 4 | 18 | 20 | 4 | 16 | 48 | 4 | 37 | 64 | 4 | 42 | 76 | 4 | 42 |
| | Subadult | 4 | 5 | 3 | 18 | 5 | 11 | 11 | 5 | 5 | 40 | 5 | 11 | 64 | 5 | 18 | 85 | 5 | 25 |
| | Overall | 7 | 9 | 7 | 20 | 9 | 14 | 15 | 9 | 11 | 43 | 9 | 24 | 64 | 9 | 29 | 81 | 9 | 33 |
| MCP 95% | 1,F,A | 7 | 88 | 5 | 4 | 88 | 4 | 10 | 89 | 7 | 35 | 13 | 9 | 55 | 3 | 19 | 74 | 1 | |
| | 2,M,S | 5 | 88 | 4 | 4 | 88 | 5 | 10 | 89 | 7 | 34 | 13 | 8 | 50 | 3 | 3 | 62 | 1 | |
| | 3,M,S | 4 | 88 | 3 | 11 | 88 | 10 | 17 | 89 | 14 | 48 | 13 | 28 | 91 | 3 | 35 | 134 | 1 | |
| | 4,F,S | 4 | 88 | 4 | 8 | 88 | 13 | 13 | 89 | 15 | 62 | 13 | 39 | 120 | 3 | 100 | 289 | 1 | |
| | 5,F,S | 2 | 88 | 2 | 17 | 88 | 16 | 13 | 89 | 12 | 96 | 13 | 46 | 138 | 3 | 27 | 194 | 1 | |
| | 6,M,S | 1 | 88 | 1 | 6 | 88 | 7 | 5 | 89 | 8 | 58 | 13 | 49 | 171 | 3 | 20 | 246 | 1 | |
| | 7,F,A | 2 | 78 | 2 | 7 | 79 | 9 | 8 | 78 | 6 | 44 | 10 | 14 | 73 | 3 | 12 | 83 | 1 | |
| | 8,F,A | 11 | 88 | 13 | 7 | 88 | 9 | 17 | 89 | 17 | 56 | 13 | 26 | 91 | 3 | 23 | 134 | 1 | |
| | 9,M,A | 18 | 88 | 15 | 24 | 88 | 22 | 42 | 89 | 24 | 123 | 13 | 29 | 168 | 3 | 30 | 203 | 1 | |
| | Male | 7 | 4 | 7 | 11 | 4 | 9 | 19 | 4 | 16 | 66 | 4 | 40 | 120 | 4 | 60 | 161 | 4 | 81 |
| | Female | 5 | 5 | 4 | 9 | 5 | 5 | 12 | 5 | 3 | 59 | 5 | 23 | 95 | 5 | 34 | 155 | 5 | 89 |
| | Adult | 9 | 4 | 7 | 11 | 4 | 9 | 19 | 4 | 16 | 65 | 4 | 40 | 96 | 4 | 50 | 124 | 4 | 60 |
| | Subadult | 3 | 5 | 2 | 9 | 5 | 5 | 11 | 5 | 4 | 60 | 5 | 23 | 114 | 5 | 46 | 185 | 5 | 90 |
| | Overall | 6 | 9 | 5 | 10 | 9 | 7 | 15 | 9 | 11 | 62 | 9 | 29 | 106 | 9 | 46 | 158 | 9 | 80 |
| MCP 100% | 1,F,A | 8 | 88 | 6 | 5 | 88 | 5 | 12 | 89 | 7 | 44 | 13 | 12 | 71 | 3 | 19 | 103 | 1 | |
| | 2,M,S | 6 | 88 | 4 | 4 | 88 | 6 | 12 | 89 | 8 | 43 | 13 | 12 | 77 | 3 | 7 | 107 | 1 | |
| | 3,M,S | 4 | 88 | 3 | 12 | 88 | 11 | 21 | 89 | 15 | 70 | 13 | 28 | 134 | 3 | 30 | 198 | 1 | |
| | 4,F,S | 5 | 88 | 5 | 10 | 88 | 15 | 17 | 89 | 19 | 87 | 13 | 39 | 173 | 3 | 66 | 345 | 1 | |
| | 5,F,S | 2 | 88 | 2 | 19 | 88 | 16 | 19 | 89 | 16 | 111 | 13 | 45 | 202 | 3 | 53 | 284 | 1 | |
| | 6,M,S | 1 | 88 | 1 | 6 | 88 | 7 | 8 | 89 | 10 | 70 | 13 | 50 | 199 | 3 | 14 | 280 | 1 | |
| | 7,F,A | 2 | 78 | 2 | 8 | 79 | 9 | 10 | 78 | 8 | 58 | 10 | 17 | 96 | 3 | 9 | 126 | 1 | |
| | 8,F,A | 12 | 88 | 13 | 8 | 88 | 10 | 20 | 89 | 19 | 73 | 13 | 33 | 123 | 3 | 32 | 182 | 1 | |
| | 9,M,A | 20 | 88 | 15 | 26 | 88 | 23 | 50 | 89 | 25 | 139 | 13 | 28 | 186 | 3 | 26 | 228 | 1 | |
| | Male | 8 | 4 | 9 | 12 | 4 | 10 | 23 | 4 | 19 | 80 | 4 | 41 | 149 | 4 | 56 | 203 | 4 | 73 |
| | Female | 6 | 5 | 4 | 10 | 5 | 5 | 16 | 5 | 4 | 74 | 5 | 26 | 133 | 5 | 54 | 208 | 5 | 104 |
| | Adult | 11 | 4 | 8 | 12 | 4 | 10 | 23 | 4 | 18 | 78 | 4 | 42 | 119 | 4 | 49 | 160 | 4 | 56 |
| | Subadult | 3 | 5 | 2 | 10 | 5 | 6 | 15 | 5 | 5 | 76 | 5 | 25 | 157 | 5 | 52 | 243 | 5 | 92 |
| | Overall | 7 | 9 | 6 | 11 | 9 | 7 | 19 | 9 | 13 | 77 | 9 | 31 | 140 | 9 | 52 | 206 | 9 | 86 |

Figure 20 shows the increase of the overall HR size with for all calculated time periods. The difference between nocturnal and diurnal HR sizes is depicted in figure 21 and demonstrates to be significant (with 90% confidence) for all three methods ($Z=-1.955$, $p=0.051$). It is also remarkable that the Kernel 95% method showed a bigger size for nocturnal HR (~30 fixes) than for the daily HR (96 fixes). It is emphasized that the spread (SD) for almost all HR estimations is remarkably high.

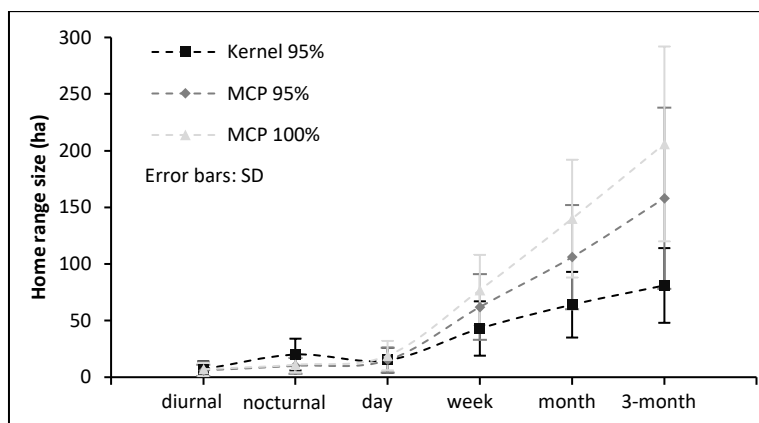


Figure 20 increase of HR size with increasing time

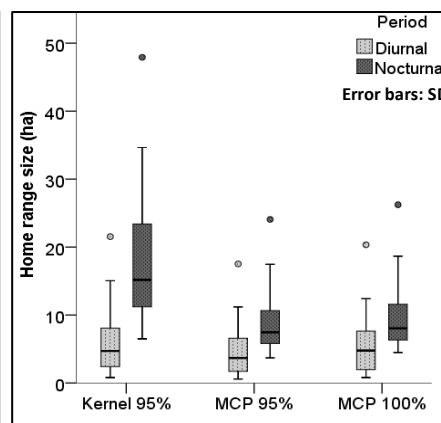


Figure 21 diurnal and nocturnal HR comparison using different methods

3.3 Circadian activity pattern

During the study period a total of 23,283, 44,618 and 6,108 suitable displacement measurements, for night, day and early morning respectively, were used to calculate a circadian activity pattern. Figure 22 depicts how the average displacement of all cats is changing during the daily cycle. The cats seemed to displace more during the night ($M=44.57$, $SD=66.17$) than day ($M=22.29$, $SD=39.68$) and there was hardly any displacement during the early morning ($M=13.41$, $SD=32.24$).

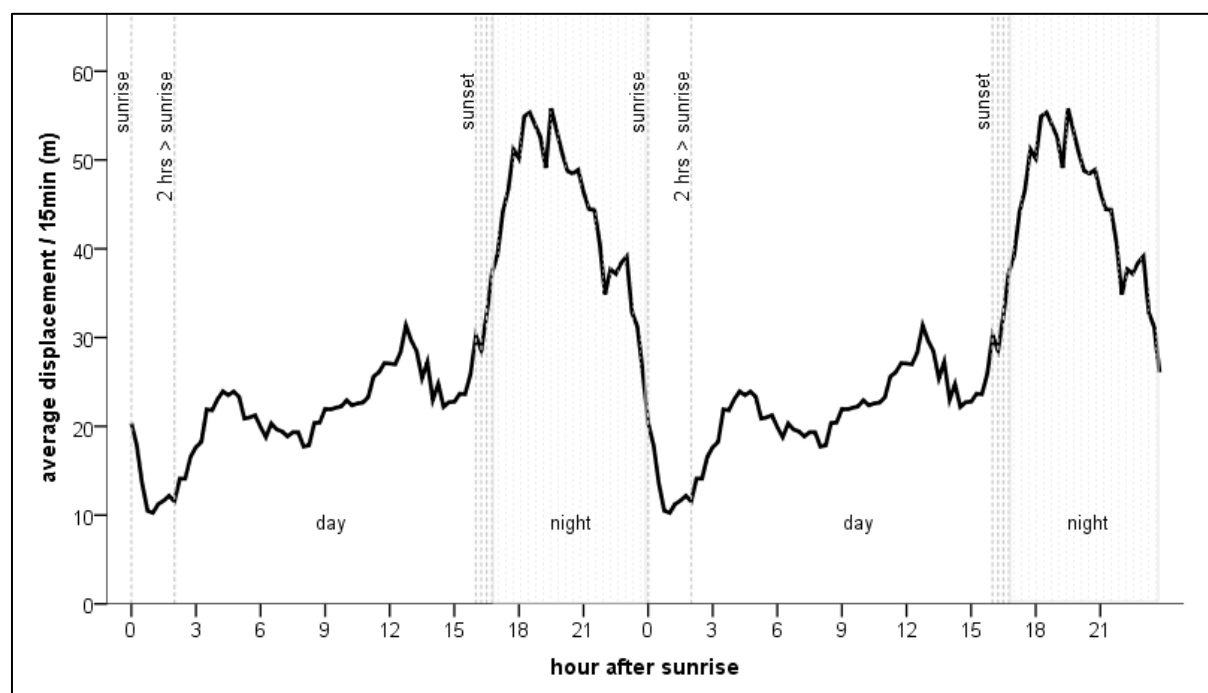


Figure 22 average displacement per 15 minutes for all cats during the circadian cycle from May - July. The areas between dashed lines indicate the three periods, night, day and early morning. The sunrise in the study period was between 05:03 and 05:51 and the sunset between 21:12 and 22:10 (CET +02:00)

The result of the LMM showed the average displacement per 15 minutes differed significantly between the three periods (LMM; $F(2,10)=29.167$, $p<0.001$), but not between sexes or age classes. The pairwise comparison showed night and day differ significantly (LMM; $M=\pm 24.71$, $SE=4.45$, 10, $p<0.001$) also night and early morning (LMM; $M=\pm 32.55$, $SE=4.45$, 10, $p<0.001$), but day and early morning did not (LMM; $M=\pm 7.84$, $SE=4.45$, 10 $p=0.108$).

3.4 Habitat use

Because the day and early morning showed no significant difference in displacement, these periods were merged. A total of 600 GPS fixes, per night and day, were randomly selected to calculate the habitat use per cat. Habitat class 'Other' is left out, because it was less than two percent of the data. All fixes were used for the graph (figure 23) while the random sample was used for the Chi-square test. From the habitat use results no clear overall pattern for all cats could be observed. Cat 1 and 4 mainly used dune habitat, cat 2 and 3 mainly used salt marsh and the for the other cats (5-9) the use of dunes or salt marsh was nearly equal.

The results of the Chi-square tests showed for eight cats the habitat use did significantly differ between day and night (table 5). Cat 3 - 7 and 9 showed an increase of 'Salt Marsh & Low Herb/Shrub' use during the night with 24%, 1%, 6%, 14% 2% and 17% respectively (figure 23). Especially cat 3 seemed to specialize on this habitat during the night. A decrease of 'Saltmarsh & High Herb' usage during the night was also observed for cat 2 - 7 and with -10%, -23%, -2%, -2%, -1%, -6% and -3% respectively. Cat 3 seemed to interchange the 'High Herb' for 'Low Herb/Shrub' during the night. For the dune habitats no pattern could be observed.

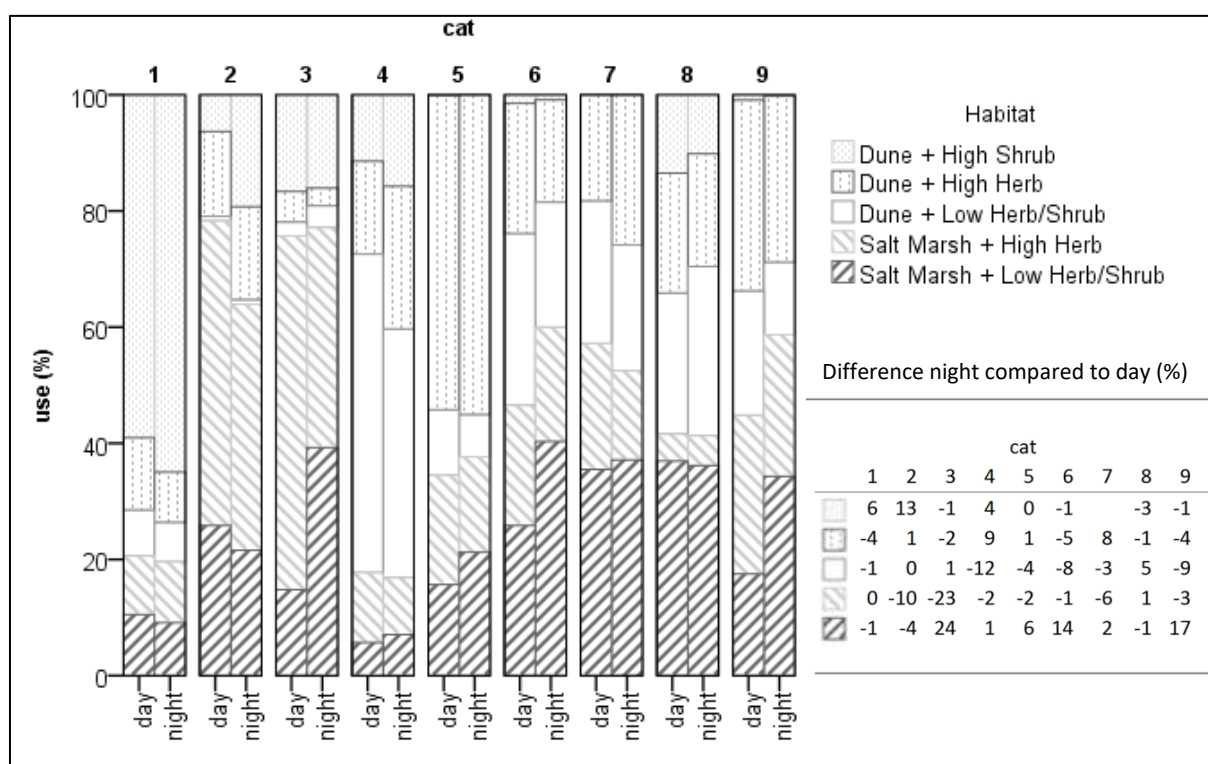


Figure 23 habitat use per cat per period

Table 5 result chi-square test with Chi-square value (χ^2), degrees of freedom (df) and significance value (p) $n = 600$

| Cat | χ^2 | df | p | Cat | χ^2 | df | p |
|-----|----------|------|--------|-----|----------|------|--------|
| 1 | 4.68 | 4 | 0.322 | 6 | 48.95 | 5 | <0.001 |
| 2 | 71.52 | 5 | <0.001 | 7 | 17.05 | 4 | 0.002 |
| 3 | 111.29 | 5 | <0.001 | 8 | 17.79 | 5 | 0.003 |
| 4 | 48.95 | 5 | <0.001 | 9 | 53.72 | 5 | <0.001 |
| 5 | 28.59 | 4 | <0.001 | | | | |

3.5 Migration vs. displacement

The differences in migration patterns between the cats is clearly visible in figure 24. The scales of the Y and X axis are from zero till the overall mean + 2*Standard Deviation, in which 95% of all values occur. The two obvious cats are cat 6 and 9. Cat 6 migrated each day relatively large distances but during such a day it hardly displaced compared to the other cats. Cat 9 on the other hand showed a similar daily migration distance, but also displaced a lot during a day; on average it covered more than four kilometre during a day. The scatterplot also shows the big variance between the cats and no clear pattern or clusters (adult/subadult or male/female) could be recognised; only cat 1 and 8 came out relatively close to each other. In table 6 the exact values per cat are given, which shows the high spread (SD) of the data.

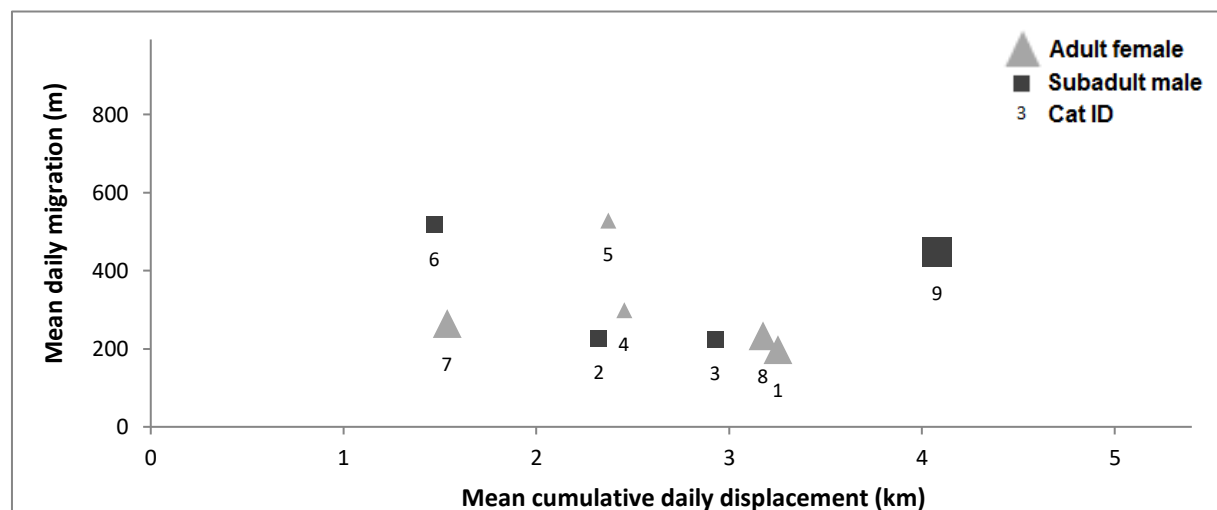


Figure 24 migration vs. displacement behaviour, indicating variances between cats

Table 6 results migrating vs. displacement behaviour, values in kilometre. *M* = mean; *SD* = Standard Deviation

| Migrating per day (m) | | | Displacement per day (km) | | |
|-----------------------|------------|-----------|---------------------------|------------|-----------|
| Cat | <i>M</i> | <i>SD</i> | Cat | <i>M</i> | <i>SD</i> |
| 1 | 198 | 141 | 1 | 3.3 | 1.1 |
| 2 | 226 | 134 | 2 | 2.3 | 0.9 |
| 3 | 225 | 161 | 3 | 2.9 | 1.0 |
| 4 | 299 | 342 | 4 | 2.5 | 1.3 |
| 5 | 528 | 435 | 5 | 2.4 | 0.9 |
| 6 | 517 | 567 | 6 | 1.5 | 0.8 |
| 7 | 265 | 199 | 7 | 1.5 | 0.9 |
| 8 | 233 | 201 | 8 | 3.2 | 1.7 |
| 9 | 446 | 293 | 9 | 4.1 | 1.3 |
| overall | 327 | 333 | overall | 2.6 | 1.4 |

3.6 Prey ingested

In total 160 scats were analysed on prey remains. The results are shown in table 7 and figure 25. Like previous years the vole was the main prey found (189 individuals, 52.6%) in the scats. No big diet shifts could be identified compared to previous years. A small, but not striking, decrease in voles and *Leporidae* and an increase of small bird could be identified for the relative frequency (R). The result from the differentiation of the *Leporidae* species showed a higher amount of rabbits in the scats. After the correction of the *Leporidae* species eaten, where several scats contain one prey, the numbers dropped from nine to four for hares and from 18 to five for rabbits. So the R of hares decreased to 1.2% and the R of rabbits to 1.5% (figure 26). Furthermore the relative volume of prey ingested (V) was compared with the R. It was striking to see (figure 26) that the nine hare and rabbit individuals took up more than 50% of the total volume ingested by the cats.

Table 7 results from scat analysis, compared with previous years. For 2014 the *Leporidae* total is the sum of *L.* unknown, hare and rabbit.

| | year | number of scats | Vole | Mice | Shrew | Rat | <i>Leporidae</i> Unknown | Hare | Rabbit | <i>Leporidae</i> total | S-birds | M-birds | L-birds | Insect | total |
|-------------------------|------|-----------------|------|------|-------|-----|--------------------------|------|--------|------------------------|---------|---------|---------|--------|-------|
| Frequency of occurrence | 2011 | 180 | 241 | 13 | 26 | 10 | - | - | - | 61 | 27 | 21 | 8 | 3 | 410 |
| | 2012 | 120 | 151 | 1 | 9 | 0 | - | - | - | 45 | 15 | 11 | 5 | 1 | 238 |
| | 2014 | 160 | 189 | 18 | 33 | 15 | 11 | 9 | 18 | 38 | 45 | 21 | 0 | 0 | 359 |
| Relative frequency % | 2011 | 180 | 58.8 | 3.2 | 6.3 | 2.4 | - | - | - | 14.9 | 6.6 | 5.1 | 2.0 | 0.7 | 100 |
| | 2012 | 120 | 63.7 | 0.4 | 3.8 | 0.0 | - | - | - | 19.0 | 6.3 | 4.6 | 2.1 | 0.0 | 100 |
| | 2014 | 160 | 52.6 | 5.0 | 9.2 | 4.2 | 3.1 | 2.5 | 5.0 | 10.6 | 12.5 | 5.8 | 0.0 | 0.0 | 100 |

3.7 Prey presence

During the small mammal trapping session there were 104 captures in total. The captures consisted out of 81 unique individuals; 36 Long-tailed field mouse (*Apodemus sylvaticus*), 33 Greater white-toothed shrew (*Crocidura russula*) and 12 voles. After calculation this resulted in a relative volume of prey present (P) value of 5.1% for voles and 19% for mice and shrews (figure 26). Quite interesting to see was that the Long-tailed field mouse is the most caught small mammal (36) but was only 5% of the total relative frequency of prey ingested (R) (table 7) by the cats. The calculation of the present volume of birds in the area resulted in a P value of 15%. Hares came out high with a P value of 61%. If the P was compared to the V (volume of prey ingested) it could be seen that cats ingest relatively more voles and birds than present and less mice, shrew and hares. Because no rabbit and rat data were available it is emphasized those species were not included in these results.

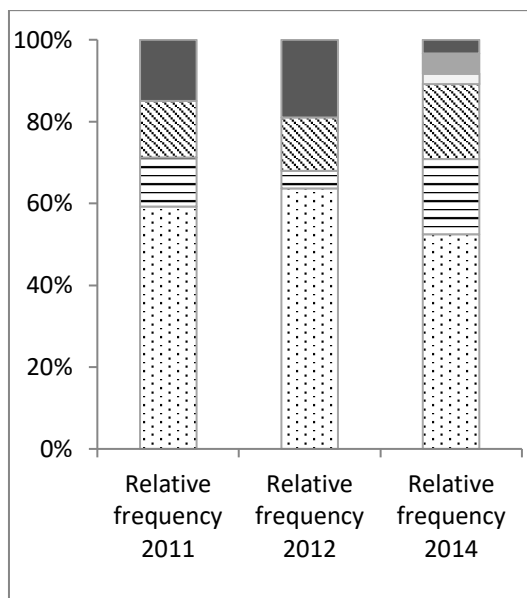


Figure 25 relative frequency of different prey groups found in scats for three years

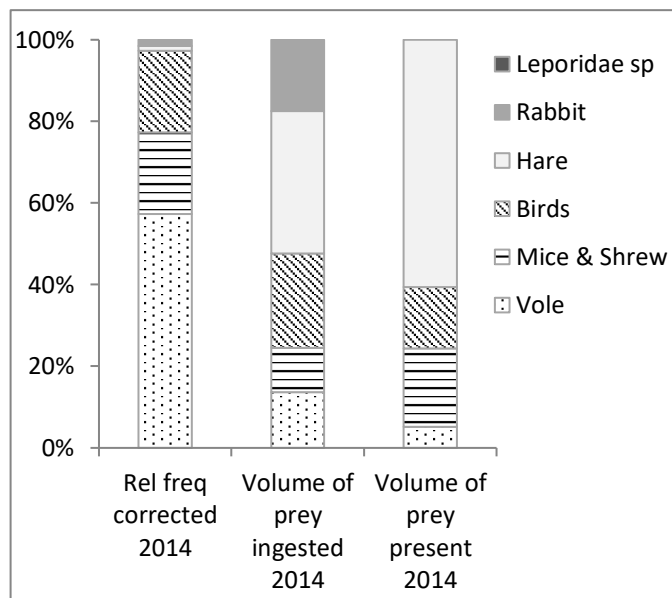


Figure 26 corrected relative frequency, volume of prey ingested and volume of prey present in research area

4 Discussion

4.1 Trapping

The trapping sessions were rather successful. In 1984 Langeveld (1987) caught one cat per 2,184 trapping hours, in our research the result was one cat per 68 hours in April and 65 in November/December. Several factors could explain this enormous difference. Langeveld applied many techniques to catch the cats, including live bait. She did use fish (mackerel and herring), but sardines in oil and a fish scent were not mentioned. Secondly, Langeveld (1987) did not mention to use a prebait while we did implemented a long prebait time. A final reason could be the growth of the cat population; increase of ~80% in 27 years (Langeveld 1987; op de Hoek 2012). It was also observed (not quantified) that the majority of the 16 cats caught in November/December were very young cats, born in the same year. This indicates successful reproduction in most parts of the research area.

It was assumed that a cat, once captured, had such a negative experience with the trap it would not return. That proved not to be true for all cats. During the April session, two tagged cats appeared at the traps during subsequent and consecutive days after capture. This was observed from cameratrap pictures available in appendix IV. In November/December five tagged cats were re-caught, and several other untagged cats were caught repeatedly also. So the reward of the bait weights up against the negative experience, at least for some cats. But the opposite is also true. The tag of cat 2 could be activated again in December, so it could be seen that he roamed around the traps regularly, without being captured and without eating from the bait. So cat 2 definitely outsmarted us.

The cats' weights ranged between 2.4 – 4.6kg. There was no impression this was heavier than house cats (~4.5kg) (Leray et al. 2006; Van Doorn 2008) as proclaimed in media sometimes (van Dalen 2013). On average the re-caught cats gained weight ($M = 0.52\text{kg}$). This was higher than observed in other studies like Bengsen et al. (2012) which even found a 14% body weight reduction on average and Bridges et al. (2015) found only 0.01kg gain (range = -0.81 - 0.94kg). It is expected that the availability of prey on Schiermonnikoog in summer is higher than winter which could explain this gain.

4.2 Home ranges

The average HR size of males was found to be bigger than females, but without statistical significance. A big variation was observed and that does coincide with other GPS studies on cats. For instance Bridges et al. (2015) found on San Clemente island, United States, an average Kernel 95% HR size of 168ha for males and 132ha for females, but this difference was not statistically significant. Bengsen et al. (2012) mentioned much bigger average HR on Kangaroo island, Australia, with 838ha for males and 516ha for females using the MCP 100% HR, but again this difference was not found to be significant. Recio et al. (2010) even calculated a MCP 100% HR of 2,486ha for a male cat which was tracked for only 18 days along a riverbed in New Zealand. Compared to our research that is seven times bigger than the largest found during 90 days. A study by Thomas et al. (2014) on 20 domestic cats in Reading, United Kingdom, showed a daily average MCP 95% HR of 1.94ha, which is much smaller compared to our research (15ha) and found no significant difference between male and

female either. Similar to our research they also found the nocturnal (2.74ha) to be bigger than the diurnal HR (1.84ha), as did Metsers et al. (2010) for two of their study sites. It shows that the cats on Schiermonnikoog use larger areas during the night and indicates a nocturnal lifestyle as their wild ancestor (*Felis silvestris lybica*) has. Cats can be very flexible and can even change to a diurnal lifestyle (Fitzgerald & Turner 2000). It could indicate that the nights on Schiermonnikoog bring something extra compared to the day and in our case it is expected that these are the nocturnal prey species on Schiermonnikoog; rabbit, hares and small rodents, and not birds. Langham (1992) found out that female cats raising kittens become diurnal. This could explain the bigger diurnal HR of cat 1 and 8 compared to the nocturnal HR (table 4).

The Kernel density estimator proved to overestimate the HR calculation with small sample sizes. That had to do with the choice of the smoothing (bandwidth) method. The smoothing variable is by far the most important input variable for the Kernel HR calculation (Fieberg 2007; Seaman & Powell 1996). Here the Plug-in bandwidth was carried out as suggested by Walter et al. (2011) and the poor performance with small sizes (Seaman & Powell 1996) taken for granted. As can be seen from figure 21 the SD is large for nocturnal HR and the average nocturnal HR size estimation comes out higher than the daily HR. That is peculiar because the daily HR also includes the nocturnal period and uses more fixes, so should be bigger. An even better example of the overestimation is the fact that the five largest HR calculated (from all HR) are nocturnal HR and thus came out even higher than the 3-month HR. The visual inspection of several HR revealed that the Plug-in bandwidth calculation performed better from weekly (N~675 fixes) HR onwards and are most trustworthy. The MCP 95% HR which also has its disadvantages like overestimation (Powell 2000), seems to be more trustworthy for the small sample size HR (diurnal, nocturnal and daily), because the overestimation that does occur is relatively small.

Finally it has to be mentioned that these nine cats are a sample of the total population on Schiermonnikoog. Much more cats were observed during the field period (~20) in the research area. So the real picture looks different of course, which much more HR that overlap presumably.

4.3 Circadian activity pattern

The circadian activity pattern shows a larger displacement distance during the night, suggesting more activity and a nocturnal lifestyle, which was also found by Langeveld (1987). It coincides with the larger average nocturnal HR. Also Langham (1992) found that the barn cats he investigated moved significantly further between dusk and dawn. We also observed a very low average displacement distance right after sunrise. However not significant ($p = 0.108$) a clear valley is still observed between 0.5 and two hours after sunrise (figure 22), suggesting a period of rest. Probably when that time interval was used instead, significance would be found. Due to the fact that the coldest moment of the day is directly after dawn this interval was chosen initially. It is difficult to explain what triggers the cats to go to rest during that particular moment, but a reason could be the energy conservation of both mammalian prey and cats during the relatively cold moment of the day (Campbell & Reece 2005). Kestler & Wilson (2014) also found the same pattern using the acceleration data from the same cats in the same study period. In figure 27 is clearly seen that relatively many time is spent on inactive behaviour (Lie) during dawn and relatively little time during dusk.

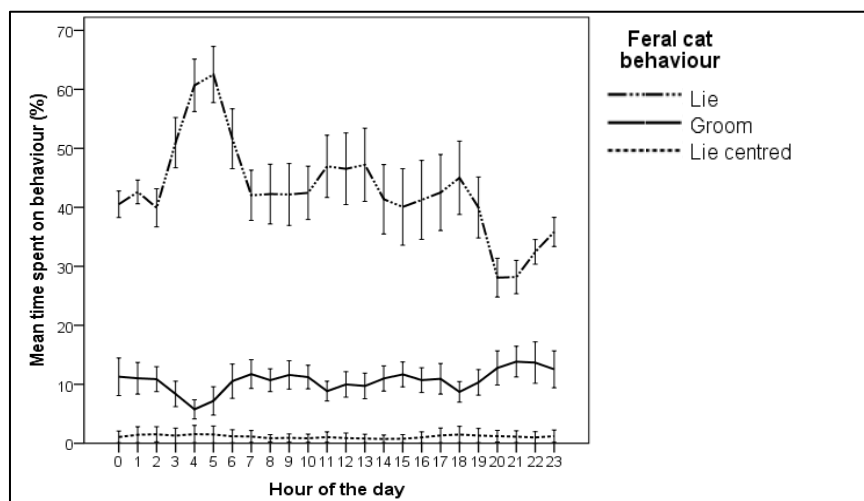


Figure 27 mean percentage of time spent (± 1 SE) on feral cat ($n=9$) behaviour for each hour of the day based on GPS time (UTC time) (to obtain local time 2 h must be added) (Kestler & Wilson 2014)

4.4 Habitat use

The result of the habitat use, showing a big variability between the cats, can suggest several things. First of all and most important, cats are real generalists which can cope with many different environmental factors, thus the arrangement of the different habitat types in the HR is of lesser importance (Liberg et al. 2000; Turner 2014). According to Liberg et al. (2000) a cat just increases the size of the HR if they cannot find enough resources (e.g. food). This indicates an important density regulator, because they found a strong relation between cat density and home range size ($R^2 = 0.9$). As example they mention that cats live in groups around garbage bins or fish dumps with >100 cats/km² and at the other end of the spectrum, <5 cats/km² are found when food is scarce.

The results show a significant difference between nocturnal and diurnal habitat use for cat 2-9. Six cats show a slight preference for 'Salt Marsh & Low Herb/Shrub' and could suggest they hunt on nocturnal prey in that habitat. It is known from rabbits to prefer to forage on short vegetation (Drees et al. 2007; van As 2011) as do hares (Kuijper & Bakker 2008). So, it is possible that cats go out at night to prey on rabbits and hares in this habitat.

If an animal uses a habitat more by than its availability (defined by HR), it is selected for. When the opposite occurs the habitat is avoided (Garshelis 2000). In our research a habitat selection analysis was not included. The most important assumptions of a selection calculation is that the animals have free and equal access to all available habitats during the study period (Garshelis 2000). For our research it proved to be impossible to achieve that assumption. A couple examples are given where it is observed or believed the cats will have no free access to the area or the access is not equal throughout the study period and thus not fulfilling the assumption:

- A Sea Gull colony, which aggressiveness to predators (cats) increase during the breeding season (personal observation) and thus become more or less unavailable for the cats;
- An inundated field in winter which gradually dries up during the summer and thus becomes more available each day;
- Areas which are temporarily flooded (unavailable), due to tidal fluctuation

- An inaccessible dense Sea Buckthorn (*Hippophae rhamnoides*) patch without any trails going through is also unavailable for cats;
- The other side of a gully which is, as the crow flies, only 20 meter but in reality a long walk for the cats;
- Presence of fellow species in an area which can induce evading or attracting behaviour
- Subadults which are accepted in the HR of the mother or siblings but not in an unrelated cat HR;

4.5 Migration vs. displacement

Natal dispersal happens mainly at young males, it also occurs at females but in a lesser extent because it is expected that the resources for females are sufficient in the natal area and are accepted by the mother more than young males (Liberg 1980). Young males migrate large distances away from the natal area and are called 'Outcasts'. They will settle at a location where no harassment of 'Breeders' (big dominant, settled, males) will occur. Once settled they fall in the category 'challengers' (mostly 2-3 years old) and will increasingly challenge 'Breeders' (Liberg 1980; Dards 1979; Kerby & Macdonald 1988). The success of mating is according to Liberg et al. (2000) strongly correlated with the dominance, age and weight of the males, indicating that 'Outcasts' and 'Challengers' have to gain weight and years before they can outcompete a 'Breeder'. In this research two 'Breeders' were caught; cat 0 and cat 9. Three young males were caught (cat 2,3,6) which were expected to be 'Outcasts' or 'Challengers'.

It is tried to identify these different categories from the migration vs. displacement behaviour (figure 28). Cat 2 and 3 are not searching for a new area to settle (low daily migration) and could be called 'Challengers'. Cat 6 does migrate long distances presumably in search for a new area to settle. He does not displace too much, probably to prevent confrontations with a 'Breeder' (cat 0), which is roaming that area also (personal observation). Cat 9 is a 'Breeder' a dominant heavy adult male (4.1kg) which is roaming the area, displacing big distances in search for females, what also coincides with the study of Langham (1992).

From cat 8 it was known to have kittens during the time of study so she stayed relatively close to her litter (low daily migration). Nevertheless she had to catch food for her youngsters, so had a large displacement. From cat 1 it was presumed to have kittens and the fact that she comes out on the same location in the scatterplot makes that assumption only stronger. From cat 7 it is known to have mated with cat 9 in May 2014, so she was assumed to be pregnant during the largest time of study. It is known from female cats to become less active as parturition nears and thus the displacement on average will be lower during the gestation phase (9 weeks) (Hart & Hart 2014). That could explain her relatively low average displacement.

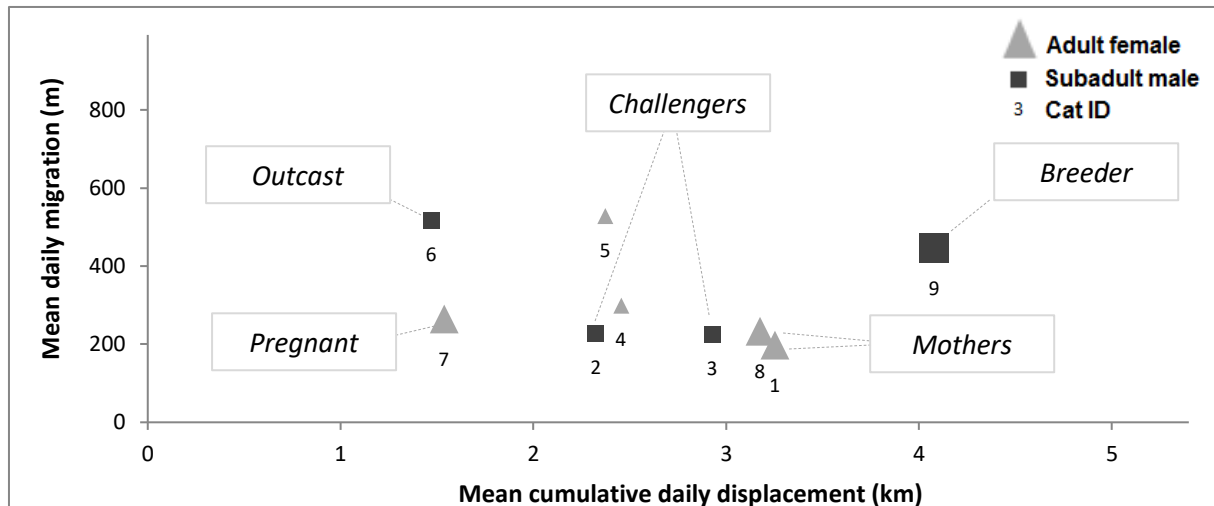


Figure 28 scatterplot showing the relation between mean daily migration and mean cumulative daily displacement, and identifying different categories of behaviour.

4.6 Prey ingested

The result from the scat analysis show that the diet of the cats remains relatively stable (~70% small rodents; ~15% *Leporidae* sp.; ~15% birds), over the three years it was studied until now (op de Hoek 2012; Maris 2013). A new insight is retrieved from the *Leporidae* hair analysis. To analyse the hairs microscopically was very time consuming, but the work was worth it. It showed that cats on Schiermonnikoog do eat both hares and rabbits and is suggesting a small preference for rabbits. It was ambiguous to translate frequency of scats found with *Leporidae* hairs to individuals eaten. In our research a conservative method was applied, maybe even too conservative which resulted in underestimation. The calculation from frequency of prey to volume of prey is very rough and can use some fine tuning; e.g. the age of the prey eaten is unknown and cubs and juveniles are lighter than adults of course; some prey might be missed in the scat analysis like chicks of birds without feathers. But overall it is a clear picture that frequency eaten or volume eaten differs enormously from each other.

4.7 Prey presence

For the small mammal trapping results it had to be assumed that all animals on a transect were caught and this might not be true. It is known that species like the voles are trap-shy and underestimation of the density might occur (Gurnell & Flowerdew 2006). Also more sophisticated methods are available to calculate density (Greenwood & Robinson 2006). However, the aim of our research was not to make an exact population estimation, the emphasize was to compare the different prey groups and compare their relative volume present in the area. A comprehensive density calculation was thus outside the scope of this study. Gurnell & Flowerdew (2006) recommend to use line transects if one wants to compare habitats, but a trapping grid setup is advised used to calculate density. On second thoughts it was better to use the trapping grid instead. Initially the idea was to identify the prey density per habitat but due to the low trapping success this idea was neglected and the data were used as a representative sample for the whole area.

The drawbacks of a availability analysis as explained already paragraph 4.4 also accounts here. A prey can be present in an area, but it is not known if it is also available for the cat e.g.:

- Young hares under a specific weight might be captured only;
- Maybe they are not even hunting on living hares (or other prey) at all, but only eat the carcasses;
- The thorns of the Sea Buckthorn might be too risky for a cat to hunt on the prey living in there (Garshelis 2000).

With the method in this research it had to be assumed the availability of prey does not fluctuate during the season, what is not true of course e.g. chicks of birds become available when hatched and unavailable when fledged again and densities of mice are the highest in autumn and lowest in early spring (Gurnell & Flowerdew 2006). July was chosen because it was the period closest towards autumn and was still during the active period of the GPS tags. Finally it had to be assumed that the numbers of birds in 2014 were the same as in 2012 (Klemann & Kleefstra 2012) and the inventory covered the whole research area systematically.

So the researcher is aware of the very rough estimations and the drawbacks of this research design, but still believes that this first explorative indication of the prey selection gives more insight in the nutritional choices of the cats.

5 Conclusion

In conclusion this study describes the spatial ecology of feral cats and give new insights in the behaviour of feral cats in a natural part of a Dutch Waddensea island. The spatio-temporal analysis techniques proved to fit the purpose and were of a pivotal role in the research. They played a crucial role in to retrieve valuable information from the GPS dataset.

The cats show to have a nocturnal lifestyle. They are more active during the night and their nocturnal HR is also bigger in most cases, which could indicate they specialize on nocturnal prey species. Males definitely do not have lager HR than females per se.

Each cat has a specific habitat use and no indication of a preferred habitat was recognised. The diurnal and nocturnal habitat use does differ significantly. A small preference for the short salt marsh vegetation during the night could be seen, what could suggest that cats hunt on prey (*Leporidae*) using that habitat. However this would need further investigation.

Although the method to relate two spatial behaviour variables and identify different behavioural categories was purely exploratory, it proved to work relatively well and different categories of cats could be recognised. It might be a useful tool for future animal tracking studies to implement.

The scat analysis showed no big shift in diet compared to previous years. Bird remains are found in the scats which still indicates a potential threat for the bird population by this introduced predator. Although our research found no indication that the cat actively search and hunt on birds, this prey group was still 23% of the total volume of prey ingested. The recalculation of frequency of prey into volume of prey showed that *Leporidae* species are a bigger part of the diet as initially thought. These findings sheds a new light on the impact of the cats on prey populations.

6 Recommendation

A HR estimator based on the Brownian Bridge Movement Model, which takes the relative speed into account, (Buchin et al. 2015) was outside the scope of this study. It can however be implemented in future research to retrieve an even better understanding in the spatial ecology of the cats. Garshelis (2000) recommends to relate population demographics (e.g. reproduction success and survival) to habitat use, but will need a long term study. The explorative study of Kestler & Wilson (2014) which take behaviour derived from the accelerometer sensor in the tag looks promising and can hopefully identify eating or even hunting behaviour in the future. That could help to indicate which areas are used by the cats to forage. Continuation of the scat analysis is also recommended to monitor the diet. Especially because voles show big fluctuations in population size (Zoogdiervereniging n.d.), it is interesting to know how the diet changes in a year with few voles present and it is recommended to take volume ingested into account besides frequency ingested. Finally I would recommend to invest time to start up an experiment where all cats are taken away from the island. I the meanwhile keep monitoring the birds as is already done systematically for a long time and compare results before and after intervention. Catching cats proved relatively easy as long as a lengthy trap habituation time and prebait time in applied, together with sardines and a fish scent. A collaboration with other Island stakeholders to exchange experiences would be of great help in such a project.

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Appendix I Python script for MCP 95% HR calculation

```

1. import numpy
2. import arcpy
3. arcpy.env.overwriteOutput = True
4. arcpy.CheckOutExtension("spatial")
5.
6. # Local variables:
7. dataset = "LOCATION\\all4_new_point_HR_UTM_py.shp"
8. temp_select = "LOCATION\\MCPtempselect"
9. temp_select2 = "LOCATION\\MCPtempselect2"
10. meanc = "LOCATION\\MCP_meancentre"
11. HR_MCP_95 = "LOCATION\\MCP_95_temp"
12. HR_MCP_95_all = "LOCATION\\MCP_95_all_daily"
13.
14. arcpy.Delete_management("LOCATION\\MCP_day.gdb/MCP_95_all_daily", "FeatureClass")
15. arcpy.CreateFeatureclass_management("LOCATION\\MCP_day.gdb", "MCP_95_all_daily", "POLY
GON", "#", "DISABLED", "DISABLED", "PROJCS['WGS_1984_UTM_Zone_32N', GEOGCS['GCS_WGS_1984'
, DATUM['D_WGS_1984', SPHEROID['WGS_1984', 6378137.0, 298.257223563]], PRIMEM['Greenwich'
, 0.0], UNIT['Degree', 0.0174532925199433]], PROJECTION['Transverse_Mercator'], PARAMETER
['False_Easting', 500000.0], PARAMETER['False_Northing', 0.0], PARAMETER['Central_Meridi
an', 9.0], PARAMETER['Scale_Factor', 0.9996], PARAMETER['Latitude_Of_Origin', 0.0], UNIT['
Meter', 1.0]];-5120900 -9998100 10000;-100000 10000;-
100000 10000;0.001;0.001;0.001;IsHighPrecision", "#", "0", "0", "0")
16. arcpy.AddField_management("LOCATION\\MCP_95_all_daily", "tag", "SHORT", "#", "#", "#", "#"
, "NULLABLE", "NON_REQUIRED", "#")
17. arcpy.AddField_management("LOCATION\\MCP_day.gdb/MCP_95_all_daily", "day", "SHORT", "#"
, "#", "#", "#", "NULLABLE", "NON_REQUIRED", "#")
18.
19. tag = 1
20. day = 54
21.
22. with arcpy.da.SearchCursor(dataset, ('tag')) as cursor:
23.     for row in cursor:
24.         query1= "tag=%s AND daynumber = %s" % (tag, day)
25.         if day > 89:
26.             break
27.         else:
28.             arcpy.Select_analysis(dataset, temp_select, query1)
29.             if int(arcpy.GetCount_management(temp_select).getOutput(0)) < 1:
30.                 tag += 1
31.                 continue
32.             else:
33.                 arcpy.MeanCenter_stats(temp_select, meanc, "", "", "")
34.                 arcpy.Near_analysis(temp_select, meanc, "#", "LOCATION", "NO_ANGLE",
"PLANAR")
35.                 rows = arcpy.SearchCursor(temp_select, "", "", "NEAR_DIST", "NEAR_DI
ST A")
36.                 list = []
37.                 for row in rows:
38.                     list.append(float(row.NEAR_DIST))
39.                 val_ni_fi = list[int(len(list)*0.95)]
40.                 query2 = "NEAR_DIST < %s" % (val_ni_fi)
41.                 arcpy.Select_analysis(temp_select, temp_select2, query2)
42.                 arcpy.MinimumBoundingGeometry_management(temp_select2, HR_MCP_95, "C
ONVEX_HULL", "", "", "NO_MBG_FIELDS")
43.                 arcpy.AddField_management(HR_MCP_95, 'tag', 'SHORT')
44.                 arcpy.CalculateField_management(HR_MCP_95, 'tag', "%s" % tag, "VB",
"")
45.                 arcpy.AddField_management(HR_MCP_95, 'day', 'SHORT')
46.                 arcpy.CalculateField_management(HR_MCP_95, 'day', "%s" % day, "VB",
"")
47.                 arcpy.Append_management(HR_MCP_95, HR_MCP_95_all, "TEST", "#", "#")
48.                 tag += 1

```

```
49.         if tag == 10:
50.             day += 1
51.             tag = 1
52.         else:
53.             continue
```

Appendix II Python script for GPS data preparation & manipulation

```
1. import csv
2. from LatLon import string2latlon
3. import os
4. from os.path import basename
5. import fiona
6. from fiona.crs import from_epsg
7. import shapely
8. from shapely.geometry import Point, LineString, Polygon, mapping
9. import utm
10. import math
11. import arcpy
12. arcpy.env.overwriteOutput = True
13.
14. input_file = 'LOCATION/all4_new.csv'
15. basename = basename(os.path.splitext(input_file)[0])
16.
17.
18. '''===== APPEND AND/OR CALCUALTE VARIABLES====='''
19.
20. # Open the csv, read it, and append the variables in the empty lists
21. tag_temp = []
22. burstID = []
23. lon = []
24. lat = []
25. hour = []
26. day = []
27. week = []
28. date = []
29. GPStime = []
30. verschil_zonop = []
31. verschil_zononder = []
32. accu = []
33.
34. infile = open(input_file)
35. reader = csv.reader(infile, delimiter=";")
36. reader.next() # skips header
37. for row in reader:
38.     tag_temp.append(int(row[1]))
39.     burstID.append(row[2])
40.     lon.append(float(row[3]))
41.     lat.append(float(row[4]))
42.     hour.append(row[5])
43.     day.append(int(row[8])-2617)
44.     week.append(int(row[9]))
45.     date.append(row[10])
46.     GPStime.append(row[12])
47.     accu.append(float(row[7]))
48.     verschil_zonop.append(int(row[18]))
49.     verschil_zononder.append(int(row[19]))
50. infile.close()
51.
52. #obtain new tagID
53. tag = []
54. for x in tag_temp:
55.     if x < 45:
56.         tag.append(x-38)
57.     else:
58.         tag.append(x-39)
59.
60. # obtain the month in number 5,6,7,8 or 9
61. month = []
62. for x in date:
63.     if x[-6] == '5':
```



```

64.         month.append(5)
65.     elif x[-6] == '6':
66.         month.append(6)
67.     elif x[-6] == '7':
68.         month.append(7)
69.     elif x[-6] == '8':
70.         month.append(8)
71.     elif x[-6] == '9':
72.         month.append(9)
73.     else:
74.         month.append(0)
75.
76. # obtain the quarter_ID per day
77. quarter_ID = []
78. quarter_label = []
79. counter = 1
80. for x in date:
81.     if counter == 1:
82.         quarter_ID.append(counter)
83.         quarter_label.append('02:00')
84.         counter += 1
85.     elif counter == 9:
86.         quarter_ID.append(counter)
87.         quarter_label.append('04:00')
88.         counter += 1
89.     elif counter == 17:
90.         quarter_ID.append(counter)
91.         quarter_label.append('06:00')
92.         counter += 1
93.     elif counter == 25:
94.         quarter_ID.append(counter)
95.         quarter_label.append('08:00')
96.         counter += 1
97.     elif counter == 33:
98.         quarter_ID.append(counter)
99.         quarter_label.append('10:00')
100.        counter += 1
101.    elif counter == 41:
102.        quarter_ID.append(counter)
103.        quarter_label.append('12:00')
104.        counter += 1
105.    elif counter == 49:
106.        quarter_ID.append(counter)
107.        quarter_label.append('14:00')
108.        counter += 1
109.    elif counter == 57:
110.        quarter_ID.append(counter)
111.        quarter_label.append('16:00')
112.        counter += 1
113.    elif counter == 65:
114.        quarter_ID.append(counter)
115.        quarter_label.append('18:00')
116.        counter += 1
117.    elif counter == 73:
118.        quarter_ID.append(counter)
119.        quarter_label.append('20:00')
120.        counter += 1
121.    elif counter == 81:
122.        quarter_ID.append(counter)
123.        quarter_label.append('22:00')
124.        counter += 1
125.    elif counter == 89:
126.        quarter_ID.append(counter)
127.        quarter_label.append('00:00')
128.        counter += 1
129.    elif counter < 96:
130.        quarter_ID.append(counter)

```

```

131.         quarter_label.append('-')
132.         counter += 1
133.     else:
134.         quarter_ID.append(counter)
135.         quarter_label.append('-')
136.         counter = 1
137.
138. #obtain the period per day
139. # 1 = night
140. # 2 = day
141. # 3 = early morning
142. period = []
143. period2 = []
144. for x in range(len(verschil_zonop)):
145.     if GPStime[x] == '00:00:00':
146.         period.append(4)
147.         period2.append(4)
148.     elif verschil_zonop[x] > 0 and verschil_zononder[x] > 0:
149.         period.append(1)
150.         period2.append(1)
151.     elif verschil_zonop[x] < -120 and verschil_zononder[x] > 0:
152.         period.append(2)
153.         period2.append(2)
154.     elif verschil_zonop[x] < 0 and verschil_zonop[x] > 120 and verschil_zononder[x] > 0:
155.         period.append(3)
156.         period2.append(2)
157.     else:
158.         period.append(1)
159.         period2.append(1)
160.
161. #period smoother
162. period3 = []
163. for x in range(len(verschil_zonop)):
164.     try:
165.         if period2[x-1] == period2[x+1] and period2[x] != period2[x-
166.         1] and period2[x] == 4:
167.             period3.append(period2[x-1])
168.         else:
169.             period3.append(period2[x])
170.     except:
171.         period3.append(period2[x])
172.
173. #obtain time after sunset
174. counter = 80
175. time_after_ss = []
176. for x in range(len(tag)):
177.     if verschil_zonop[x] > -16 and verschil_zonop[x] < 0:
178.         counter = 0
179.         time_after_ss.append(counter)
180.         counter += 1
181.     elif counter > 94:
182.         time_after_ss.append(counter)
183.         counter = 0
184.     else:
185.         time_after_ss.append(counter)
186.         counter += 1
187.
188. #obtain sunday count
189. sun_dayc = 1
190. sun_day = []
191. for x in range(len(tag)):
192.     if burstID[x] == '1':
193.         sun_dayc = 1
194.         sun_day.append(sun_dayc)
195.     elif time_after_ss[x] == 0 and time_after_ss[x-1] != 0:
196.         sun_dayc += 1

```

```

197.         sun_day.append(sun_dayc)
198.     else:
199.         sun_day.append(sun_dayc)
200.
201. #obtain male female
202. sex = []
203. for x in tag:
204.     if x == 1 or x == 4 or x == 5 or x == 7 or x == 8:
205.         sex.append('female')
206.     else:
207.         sex.append('male')
208.
209. #obtain age
210. age = []
211. for x in tag:
212.     if x == 1 or x == 7 or x == 9 or x == 8:
213.         age.append('adult')
214.     else:
215.         age.append('subadult')
216.
217. # smoother; recalculate missing points (1) and accuracy using the successive and previous point
218. lon1 = []
219. lat1 = []
220. accu1 = []
221. for x in range(len(lon)):
222.     if tag[x] == tag[x-1] and lon[x] < 1 and lon[x-1] > 1 and lon[x+1] > 1:
223.         lon1.append(str((lon[x-1] + lon[x+1]) / 2))
224.         lat1.append(str((lat[x-1] + lat[x+1]) / 2))
225.         accu1.append((accu[x-1] + accu[x+1]) / 2)
226.     else:
227.         lon1.append(str(lon[x]))
228.         lat1.append(str(lat[x]))
229.         accu1.append(accu[x])
230.
231. #create LatLon List for UTM conversion (used for angle & distance calculation)
232. latlon = []
233. for x in range(len(lon)):
234.     latlon.append(string2latlon(lat1[x], lon1[x], 'D%', 'D%'))
235.
236. #conversion from Decimal Degrees to UTM in m.
237. UTM_temp = []
238. for x in range(len(lat1)):
239.     UTM_temp.append(utm.from_latlon(float(lat1[x]), float(lon1[x])))
240.
241. #Loop to obtain only the x(easting) and y(northing) UTM coordinates
242. UTM_E = []
243. UTM_N = []
244. for E, N, zone_n, zone_l in UTM_temp:
245.     UTM_E.append(float(round(E,1)))
246.     UTM_N.append(float(round(N,1)))
247.
248.
249. '''=====CALCULATE first DISTANCE between GPS MEASUREMENTS====='''
250.
251. # Calculate distance in m
252. distance = []
253. for x in range(len(latlon)):
254.     if burstID[x] == '1':
255.         distance.append(0)
256.     elif lon1[x] == '0.0' or lon1[x-1] == '0.0':
257.         distance.append(0)
258.     else:
259.         distance.append(round(float(latlon[x].distance(latlon[x-1])*1000),2))
260.
261.
262.

```

```

263.
264. '''===== IDENTIFY SPIKES AND SMOOTH LOCATION====='''
265.
266. # calculate cosinus(angle)
267. cos = []
268. for a in range(len(latlon)):
269.     try:
270.         cos.append((((UTM_E[a+1]-UTM_E[a-1])**2 + (UTM_N[a+1]-UTM_N[a-1])**2) -
                ((UTM_E[a]-UTM_E[a-1])**2 + (UTM_N[a]-UTM_N[a-1])**2) - ((UTM_E[a+1]-
                UTM_E[a])**2 + (UTM_N[a+1]-UTM_N[a])**2)) /
271.         (-2 * math.sqrt((UTM_E[a]-UTM_E[a-1])**2 + (UTM_N[a]-UTM_N[a-
                1])**2) * math.sqrt((UTM_E[a+1]-UTM_E[a])**2 + (UTM_N[a+1]-UTM_N[a])**2)))
272.     except:
273.         cos.append(1)
274.
275. #calculate degrees angle
276. degrees = []
277. for a in range(len(latlon)):
278.     try:
279.         if cos[a] == 1:
280.             degrees.append(180)
281.         elif cos[a] == 0.0000:
282.             degrees.append(0)
283.         else:
284.             degrees.append(180 - math.degrees(math.acos(cos[a])))
285.     except:
286.         degrees.append(2000)
287.
288. #assign spikes
289. spike = []
290. for x in range(len(latlon)):
291.     try:
292.         if burstID[x] == '1':
293.             spike.append(0)
294.         elif lon1[x] == '0.0' or lon1[x-1] == '0.0' or lon1[x+1] == '0.0':
295.             spike.append(0)
296.         elif distance[x] < 16.9 and degrees[x] >160 and degrees[x] <200:
297.             spike.append(1)
298.         else:
299.             spike.append(0)
300.     except:
301.         spike.append(0)
302.
303. #smoother; recalculate spikes using the successive and previous point
304. lon2 = []
305. lat2 = []
306. for x in range(len(lon)):
307.     try:
308.         if spike[x] == 1:
309.             lon2.append(str((float(lon2[x-1]) + float(lon1[x+1])) / 2))
310.             lat2.append(str((float(lat2[x-1]) + float(lat1[x+1])) / 2))
311.         else:
312.             lon2.append(str(lon1[x]))
313.             lat2.append(str(lat1[x]))
314.     except:
315.         lon2.append(str(lon1[x]))
316.         lat2.append(str(lat1[x]))
317.
318. #create second LatLon List for UTM conversion (used for angle & distance calculation)
319. latlon2 = []
320. for x in range(len(lon)):
321.     latlon2.append(string2latlon(lat2[x], lon2[x], 'D%', 'D%'))
322.
323. #conversion from Decimal Degrees to UTM in m.
324. UTM_temp = []
325. for x in range(len(lat1)):
326.     UTM_temp.append(utm.from_latlon(float(lat2[x]), float(lon2[x])))

```

```

327.
328. # Loop to obtain only the x(easting) and y(northing) UTM coordinates
329. UTM_E = []
330. UTM_N = []
331. for E, N, zone_n, zone_l in UTM_temp:
332.     UTM_E.append(int(E))
333.     UTM_N.append(int(N))
334.
335.
336. '''=====SET ALL COORINATES WITH HORIZON ACC >40m TO 1====='''
337.
338. delete = []
339. for x in range(len(lon)):
340.     if accu1[x] > 40:
341.         delete.append(1)
342.     else:
343.         delete.append(0)
344.
345.
346. '''=====CALCULATE SECOND & THIRD DISTANCE BETWEEN GPS MEASUREMENTS====='''
347.
348. # Calculate distance in m again after smoothing without measurements with acc >40m
349. distance2 = []
350. for x in range(len(latlon)):
351.     if burstID[x] == '1':
352.         distance2.append('-')
353.     elif delete[x] == 1 or delete[x-1] == 1:
354.         distance2.append('-')
355.     else:
356.         distance2.append(round(float(latlon2[x].distance(latlon2[x-1]))*1000,2))
357.
358. # Calculate distance in m again after smoothing with measurements with acc >40m
359. distance3 = []
360. for x in range(len(latlon)):
361.     if distance2[x] == '-':
362.         distance3.append(distance[x])
363.     else:
364.         distance3.append(distance2[x])
365.
366.
367. '''=====WRITE DATA TO OUTPUT====='''
368.
369. output = 'D:/GISUNIGIS/Thesis/Data_GIS_Analysis/Scripts/Outputs/' + basename + '_out.csv'
370.
371. # Export the GPS measurements together with the calculated parameters as .csv
372. outfile = open(output, "wt")
373. writer = csv.writer(outfile, delimiter = ";", lineterminator = '\n')
374. writer.writerow( ('Id', 'tag', 'sex', 'age', 'burstID', 'date', 'GPStime', 'month', 'week',
    'daynumber', 'period', 'period2', 'period3', 'verschil_zonop', 'verschil_zononder',
    'time_after_ss', 'sunday', 'hour', 'quarter_ID', 'quarter_label', 'distance1', 'distance2',
    'distance3', 'spike', 'delete', 'angle_deg', 'lon', 'lat', 'accu' ))
375. for x in range(len(tag)):
376.     writer.writerow((x+1, tag[x], sex[x], age[x], burstID[x], date[x], GPStime[x],
    month[x], week[x], day[x], period[x], period2[x], period3[x], verschil_zonop[x], verschil_zononder[x],
    time_after_ss[x], sun_day[x], hour[x], quarter_ID[x], quarter_label[x], distance[x], distance2[x],
    distance3[x], spike[x], delete[x], degrees[x], lon2[x], lat2[x], accu1[x]))
377. outfile.close()
378.
379.
380. '''=====CREATE POINTS OF THE GPS MEASUREMENTS====='''
381.
382. # Create individual points and appends them to the lists
383. points = []
384. for x in range(len(latlon)):
385.     point = Point(float(lon2[x]), float(lat2[x]))

```

```

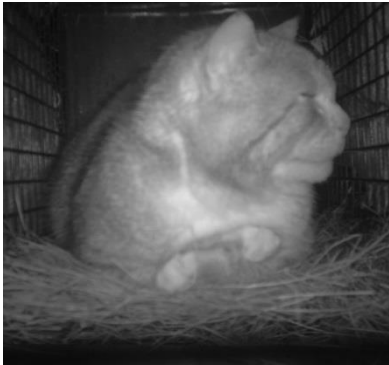
386.     points.append(point)
387.     '''=====WRITE DATA TO OUTPUT SHAPEFILES====='''
388.
389. output_shp2p = 'D:/GISUNIGIS/Thesis/Data_GIS_Analysis/Scripts/Outputs/' + basename + '_
    point_HR_may-sept.shp'
390.
391. # Export the GPS measurements as shapefile, and adds the daynumber, time and behaviour
    as attributes
392. schema = {'geometry': 'Point', 'properties': {'Id': 'int', 'tag': 'int', 'sex': 'str', '
    age': 'str', 'month': 'int', 'week': 'int', 'daynumber': 'int', 'quarterID': 'int', '
    distance3': 'float', 'delete': 'int' },}
393.
394. c = 0 #starts a counter where the loop can work with
395. with fiona.open(output_shp2p, 'w', 'ESRI Shapefile', schema) as b:
396.     for k in points:
397.         if c < len(points):
398.             b.write({'geometry': mapping(k), 'properties': {'Id': c+1, 'tag': tag[c], 'se
    x': sex[c], 'age': age[c], 'month': month[c], 'week': week[c], 'daynumber': day[c], 'qu
    arterID': quarter_ID[c],
399.                 'distance3': distance3[c], 'delete': delete[c]}})
400.             c += 1
401.
402.
403.     '''=====CONVERT FROM DECIMAL DEGREES TO RD and UTM USING ARCPY====='''
404.
405. #to UTM
406. output_shp3p = 'D:/GISUNIGIS/Thesis/Data_GIS_Analysis/Scripts/Outputs/' + basename + '_p
    oint_UTM.shp'
407. arcpy.Project_management(output_shp2p, output_shp3p, "PROJCS['WGS_1984_UTM_Zone_32N', GEO
    GCS['GCS_WGS_1984', DATUM['D_WGS_1984', SPHEROID['WGS_1984', 6378137.0, 298.257223563]], PRI
    MEM['Greenwich', 0.0], UNIT['Degree', 0.0174532925199433]], PROJECTION['Transverse_Mercator
    '], PARAMETER['False_Easting', 500000.0], PARAMETER['False_Northing', 0.0], PARAMETER['Centr
    al_Meridian', 9.0], PARAMETER['Scale_Factor', 0.9996], PARAMETER['Latitude_Of_Origin', 0.0],
    UNIT['Meter', 1.0]]", "#", "GEOGCS['GCS_WGS_1984', DATUM['D_WGS_1984', SPHEROID['WGS_1984', 6
    378137.0, 298.257223563]], PRIMEM['Greenwich', 0.0], UNIT['Degree', 0.0174532925199433]]")
408.
409. #to RD
410. output_shp4p = 'D:/GISUNIGIS/Thesis/Data_GIS_Analysis/Scripts/Outputs/' + basename + '_p
    oint_RD.shp'
411. arcpy.Project_management(output_shp2p, output_shp4p, "PROJCS['RD_New', GEOGCS['GCS_Amersf
    oort', DATUM['D_Amersfoort', SPHEROID['Bessel_1841', 6377397.155, 299.1528128]], PRIMEM['Gre
    enwich', 0.0], UNIT['Degree', 0.0174532925199433]], PROJECTION['Double_Stereographic'], PARA
    METER['False_Easting', 155000.0], PARAMETER['False_Northing', 463000.0], PARAMETER['Central
    _Meridian', 5.38763888888889], PARAMETER['Scale_Factor', 0.9999079], PARAMETER['Latitude_Of
    _Origin', 52.15616055555555], UNIT['Meter', 1.0]]", "Amersfoort_To_WGS_1984_2008_MB", "GEOGC
    S['GCS_WGS_1984', DATUM['D_WGS_1984', SPHEROID['WGS_1984', 6378137.0, 298.257223563]], PRIME
    M['Greenwich', 0.0], UNIT['Degree', 0.0174532925199433]]")

```

Appendix III Python script for mean daily migration calculation

```
1. import numpy
2. import arcpy
3. arcpy.env.overwriteOutput = True
4. arcpy.CheckOutExtension("spatial")
5.
6.
7.
8. # Local variables:
9. dataset = "LOCATION\\all4_new_point_HR_UTM_py.shp"
10. temp_select = "LOCATION\\daily_migr.gdb\\tempselect"
11. meanc = "LOCATION\\daily_migr.gdb\\meancentre"
12. Day_migr_all = "LOCATION\\daily_migration_all"
13.
14. arcpy.Delete_management(Day_migr_all,"FeatureClass")
15. arcpy.CreateFeatureclass_management("LOCATION\\daily_migr.gdb","daily_migration_all",
    "POINT","#","DISABLED","DISABLED","PROJCS['WGS_1984_UTM_Zone_32N',GEOGCS['GCS_WGS_1
    984',DATUM['D_WGS_1984',SPHEROID['WGS_1984',6378137.0,298.257223563]],PRIMEM['Greenw
    ich',0.0],UNIT['Degree',0.0174532925199433]],PROJECTION['Transverse_Mercator'],PARAM
    ETER['False_Easting',500000.0],PARAMETER['False_Northing',0.0],PARAMETER['Central_Me
    ridian',9.0],PARAMETER['Scale_Factor',0.9996],PARAMETER['Latitude_Of_Origin',0.0],UN
    IT['Meter',1.0]];-5120900 -9998100 10000;-100000 10000;-
    100000 10000;0.001;0.001;0.001;IsHighPrecision","#","0","0","0")
16. arcpy.AddField_management(Day_migr_all,"tag","SHORT","#","#","#","#","NULLABLE","NON
    _REQUIRED","#")
17. arcpy.AddField_management(Day_migr_all,"day","SHORT","#","#","#","#","NULLABLE","NON
    _REQUIRED","#")
18.
19.
20. import arcpy
21.
22. tag = 1
23. day = 1
24.
25. with arcpy.da.SearchCursor(dataset, ('tag')) as cursor:
26.     for row in cursor:
27.         query1= "tag=%s AND daynumber = %s" % (tag, day)
28.         if tag > 9:
29.             break
30.         else:
31.             arcpy.Select_analysis(dataset, temp_select, query1)
32.             if int(arcpy.GetCount_management(temp_select).getOutput(0)) < 1:
33.                 day += 1
34.                 continue
35.             else:
36.                 arcpy.MeanCenter_stats(temp_select, meanc, "", "", "")
37.                 arcpy.AddField_management(meanc, 'tag', 'SHORT')
38.                 arcpy.CalculateField_management(meanc, 'tag', "%s" % tag, "VB", "")
39.
40.                 arcpy.AddField_management(meanc, 'day', 'SHORT')
41.                 arcpy.CalculateField_management(meanc, 'day', "%s" % day, "VB", "")
42.
43.                 arcpy.Append_management(meanc, Day_migr_all,"NO_TEST","#","#")
44.                 day += 1
45.                 if day == 90:
46.                     tag += 1
47.                     day = 1
48.                 else:
49.                     continue
```


Appendix IV Cat pictures and detailed information



Cat 0 Chris (trapped)



Cat 0 Chris (with tag)



Cat 1 Sharon



Cat 2 Martinus



Cat 3 Erik



Cat 3 Erik



Cat 4 Corrie



Cat 5 Thea



Cat 6 Eduardo (with tag)



Cat 6 Eduardo



Cat 7 Mevrouw Langeveld



Cat 8 Ilse



Kittens Cat 8



Cat 9 Rick

Fieldform caught cats, feral cat project Schiermonnikoog 2014

| Cat # | Trap # | Tag # | Date Caught | Time caught | Est. Weight | Weight | Tail | Body | Skull | Fur colour | Sex | Neutered | PIT tag | Reproductive status | Teeth condition | | | | Overall Cond | Age | Name |
|-------|--------|-------|-------------|-------------|-------------|--------|------|------|-------|------------------|-----|----------|---------|-----------------------|-------------------|-----------------|-------------------|-----------------------------|----------------|-----------------|----------------|
| | | | | | | | | | | | | | | | Tartar | Missing | Wear | Gum | Footpar | | |
| | | | | | | | | | | | | | | | 1(none) - 5(many) | # tooth # molar | 1(none) - 5(many) | 1pink 2white 3red 4infected | | 1juv 2subad 3ad | |
| 0 | 15 | 38 | 06/04/14 | 21:30 | 4.6 | >2,3kg | 29 | 52 | 10.5 | tabby white | M | N | N | Big testes | 1 | none | 4 | 1 | Y (ticks) | 4 | Chris |
| 1 | 12 | 39 | 07/04/14 | 11:40 | 3.3 | 3.3 | 24.5 | 46 | 9.4 | turtle | F | - | N | nipples | 1 | none | 1 | 1 | Y (flea ticks) | 4 | Sharon |
| 2 | 5 | 40 | 12/04/14 | 10:30 | 2.6 | 2.6 | 30 | 48 | 9.6 | tabby | M | N | N | small testes | 1 | none | 1 | 1 | Y (ticks) | 3 | Martinus |
| 3 | 3 | 41 | 13/04/14 | 21:30 | 2.6 | 2.6 | 25 | 46 | 9.2 | Red | M | N | N | Big testes | 1 | none | 1 | 1 | Y (ticks) | 3.5 | Erik |
| 4 | 6 | 42 | 07/04/14 | 12:45 | 2.6 | 2.6 | 22.5 | 45 | 8.9 | black | F | - | N | no reproduction | 1 | none | 1 | 1 | Y (ticks) | 2.5 | Corri |
| 5 | 30 | 43 | 12/04/14 | 21:30 | 2.4 | 2.4 | 24 | 46 | 9 | tabby white | F | - | N | no reproduction | 1 | none | 1 | 1 | Y (ticks) | 4 | Thea(o) |
| 6 | 13 | 44 | 06/04/14 | 21:00 | 3 | 3 | 27 | 48 | 9.5 | marble | M | N | N | Big testes | 1 | none | 1 | 1 | Y (ticks) | 4 | Eduardo |
| 7 | 22 | 46 | 13/04/14 | 07:00 | 3.5 | 3.6 | 28 | 50 | 9.3 | tabby | F | - | N | nipples, no mammaries | 1 | none | 1 | 1 | Y (ticks) | 4 | Mevr Langeveld |
| 8 | 14 | 47 | 13/04/14 | 19:44 | 2.8 | 2.8 | 24 | 45 | 9.3 | tabby white grey | F | - | N | nipples, no mammaries | 1 | none | 1 | 1 | Y (ticks) | 4 | Ilse |
| 9 | 21 | 48 | 13/04/14 | 00:15 | 4.1 | 4.1 | 30 | 52 | 10.4 | tabby white | M | N | N | Big testes | 2 | none | 2 | 1 | Y (ticks) | 4.5 | Rick |