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Structure and ecology of colonies of free-roaming cats (*Felis silvestris catus*) in urban environment (Porto, Portugal)

Bruna Ramalho Maciel

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Dissertação de Mestrado apresentada à
Faculdade de Ciências da Universidade do Porto em
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Departamento de Biologia

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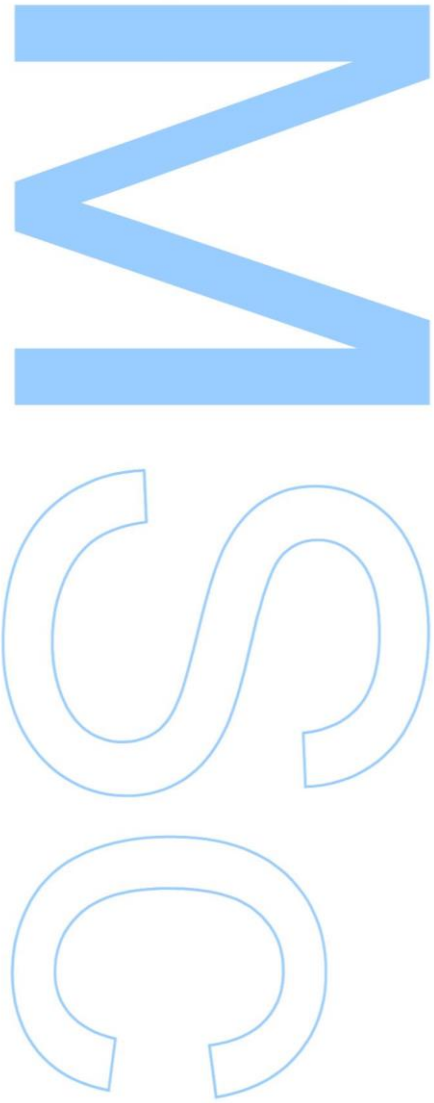
Orientador

Professor Dr. Alexandre Carlos Nogueira Valente

Todas as correções determinadas pelo júri, e só essas, foram efetuadas.
O Presidente do Júri,

Porto, _____/_____/_____



Structure and ecology of colonies of free-roaming cats (*Felis silvestris catus*) in urban environment (Porto, Portugal)

Acknowledgements

I would like to thank the Faculdade de Ciências do Porto (FCUP). Also thank the Professor Doctor Alexandre Valente. As well as the associations “Animais de Rua” in special the Dr.ª Cláudia Neves, and to “MIACIS - Protecção e Integração Animal” for the information and contributions for this study. A thank you as well for the cat caretakers from São Roque, Dona Maria José, and from Falcão, Dona Paulina, as well as São Roque Park staff. To the Porto City Council and in particular to Dr.ª Ana Moura. Ana Ferraz that helped during the visits to the colony areas. I also would like to thank my parents and brother for all the support.

Abstract

Porto shelters many cat colonies (*Felis silvestris catus*), that often are source of conflict between humans and animals. Those colonies of free roaming cats, most commonly formed by previously owned, domestic lineage or animals that are allowed to roam by the owners. Also, they reproduce at a fast rate and are highly adaptable, easily causing increases in population. The most common methods of mitigation of the cat population are euthanasia and Trap-Neuter-Release (TNR) programs. Therefore, knowledge of those urban colonies may be helpful to create strategies future interventions of mitigation.

In this study, several colonies were monitored between August, 2019 and March, 2020. Colonies were located in Bela Vista and Campanhã neighborhoods, Porto-Portugal. The monitoring consisted of monthly visits during morning, afternoon and night periods. However, the access to Saint Roque Park was not possible during the night so the colony was monitored using trap-cameras from November, 2019. During the monitoring visits photographs of cat sightings allowed registration of cat presence, its location and whenever possible sex. The data obtained was added to an ArcGis file for spatial analysis of area. Cat frequency and area used were subjected to statistical analysis.

One hundred and fifty cats were observed at least once during this study, among seven locations. Feeding spots replenished by caretakers handouts location and periodicity was also registered. Two colonies were target of TNR procedures during the study period, The first was in September 2019 at Saint Roque park colony (Park) and the second in January 2020 at the Cooperativa do Pego Negro Street and Reinaldo Oudinot colony (Oudinot). Even if it is expected that colonies density will decrease, the short duration of the study was not enough to detect any change except the fact that no new litters occurred. Future studies are therefore needed to verify long term effects of the TNR. It was possible to observe that the cat activity and area used was highly focused in food handouts. Park colony showed a larger area and lower density of cats, followed by the Oudinot colony. The other three colonies occupy smaller areas and have higher cat densities, but no statistical significantly differences between them were found. The Kernel Density Estimation (KDE) also shows that the home range of the individuals in the colony tend to overlap.

The level of disturbance was one of the factors that seems to affect cat numbers in a colony, the presence and spotting was also heavily influenced by the feeding spots. However no statistically difference was sex related. However, KDE does suggests that neutered cats use smaller areas. As no new litters were seen after TNR procedures is a promising fact, confirms

the effectivity TNR. More wide spread studies also however necessary to fully access its long term results.

Keywords: Home range, free-roaming cats, TNR. Porto, urban environment, *Felis silvestris catus*

Resumo

Porto abriga muitas colônias de gatos (*Felis silvestris catus*), isso é uma fonte de conflitos entre humanos e animais. Essas colônias de gatos de vida livre são comumente formadas por gatos que possuíam donos, de linhagem doméstica ou que são permitidos a exploração pelos donos. Além disso, eles se reproduzem em uma taxa rápida e são altamente adaptáveis, causando facilmente aumentos na população. Os métodos mais comuns de mitigação da população de gatos, são a eutanásia e programas de Capturar-Esterilizar-Devolver (CED). Desta forma, o conhecimento dessas colônias urbanas pode ser útil na criação de futuras estratégias de mitigação.

Nesse estudo, várias colônias foram monitoradas entre agosto de 2019 a março de 2020. Colônias estavam localizadas nos bairros de Bela Vista e Campanhã, Porto-Portugal. O monitoramento consistia em visitas mensais nos períodos matutino, vespertino e noturno. Porém, o acesso ao Parque São Roque não foi possível durante a noite, então a colônia foi monitorada por armadilhas fotográficas a partir de novembro de 2019. Durante as visitas de monitoramento, fotografias de avistamentos de gatos permitiram o registro da presença do gato, sua localização e, sempre que possível, sexo. Os dados obtidos foram adicionados a um arquivo no ArcGis para análise espacial de área. A frequência e a área utilizadas pelos gatos foram submetidas à análise estatística.

Cento e cinquenta gatos foram observados pelo menos uma vez durante este estudo, de entre sete localizações. A localização e periodicidade das ofertas de alimentos dos cuidadores também foram registradas. Duas colônias foram alvo de procedimentos de CED durante o período do estudo, a primeira foi em setembro de 2019 na colônia Parque São Roque (Park) e a segunda em janeiro de 2020 na rua Cooperativa do Pego Negro e colônia Reinaldo Oudinot (Oudinot). Mesmo que seja esperado que a densidade das colônias diminua, a curta duração do estudo não foi suficiente para detectar qualquer mudança, exceto o fato de que não ocorreram novas ninhadas. Estudos futuros são, portanto, necessários para verificar os efeitos de longo prazo do CED. Foi possível observar que a atividade dos felinos e a área utilizada eram altamente focadas na distribuição de alimentos. A colônia Park apresentou maior área e menor densidade de gatos, seguida da colônia Oudinot. As outras três colônias ocupam áreas menores e têm maior densidade felina, mas não foram encontradas diferenças estatisticamente significativas entre elas. A estimativa de densidade do kernel (KDE) também mostra que a área de vida dos indivíduos na colônia tende a se sobrepor.

O nível de perturbação foi um dos fatores que parece afetar o número de gatos em uma colônia, a presença e observações também foram fortemente influenciadas pelos pontos de alimentação. No entanto, nenhuma diferença estatística foi relacionada ao sexo. Entretanto, o KDE sugere que os gatos castrados usem áreas menores. Como não foram observadas novas ninhadas após os procedimentos de CED é um fato promissor que confirma a efetividade do CDE. Estudos mais amplos também são necessários para acessar plenamente seus resultados de longo prazo.

Palavras chave: Área de vida, gatos de vida livre, CED, Porto, ambiente urbano, *Felis silvestris catus.*

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List of acronyms

TNR	Trap-Neuter-Release
MCP	Minimum Convex Polygon
KDE	Kernel Density Estimation
rhr	Reproducible home Range
Park	Saint Roque park
Oudinot	Cooperativa do Pego Negro Street and Reinaldo Oudinot
Casimiro	Maestro Raúl Casimiro Street
Silva	Fernando Moreira da Silva Street
Mendes	João Espregueira Mendes Street
Aventino	Sport Complex Monte Aventino
Antas	Antas Street

Introduction

The presence of free-roaming cats, *Felis silvestris catus,* in the urban areas is a problem identified in several cities around the world (Brickner, 2003; Cabral et al., 2005; Finkler et al., 2011; Gomes et al., 2017; Monterroso et al., 2009a; Moseby et al., 2015; Natoli et al., 2006; Pillay et al., 2018; Sarmento et al., 2009). These animals are not confined to a house and may not have an owner, where ownership only is identifiable whenever the animal carries a collar externally, however since 2019 they are also required to have microchips. These animals are often not socialized or will only approach a caregiver. Despite the lack of identifiers, often those felines are at a feral state, that can be defined by the low to no tolerance to human contact, usually not allowing approximation, as well as independence from humans, even when using the food resources available from humans (Turner & Bateson, 2000). Feral cats search for resources and shelter in the urban environment, therefore the landscape can influence animal presence and density. They also tend to have a shorter lifespan than their domestic counterparts, and most likely will get defensive or cower and try to hide when trapped (Gosling et al., 2013).

Free-roaming cats can live in a solitary lifestyle or in colonies. This behavior choice is directly associated with resources availability and density of individuals (Turner & Bateson, 2000). Those felines tend to concentrate in areas with trustworthy feeding spots, influencing a larger density and distribution (Liberg et al., 2000; Mirmovitch, 1995; Tennent, 2005). Habitat does influence the density, however, areas with no permanent feeding spots have lower densities and areas with more than one do tend to have larger densities (Tennent & Downs, 2008b). This resource is influenced by human interaction, it increases the lifespan and fertility of the cats and cause them to roam less, concentrating the impact they have in smaller areas (Schmidt et al., 2007). Seemly there was less territory confront when there was less effort needed to acquire food resources (Tennent & Downs, 2008b; Warner, 1985). This was also an important factor on the density of the cats as they tend to stay close to the supplementary feeding spots (Tennent & Downs, 2008b; Warner, 1985). Those places also facilitate the occurrence of colonies where the prey normally wouldn't be enough (Turner & Bateson, 2000), stimulating the formation of social groups (Carol Haspel & Calhoon, 1993).

Cat colonies formed are matriarchal, the dominance being set by how closely related an individual cat is to the dominant female. Females also have higher level of interaction with members of their own lineage, where care is offered to youngers by multiple females, not only the kitten's mother (Baker et al., 2005). The cats can have litters year round, however normally have an increased value of litters in spring and end of summer (Jones & Coman, 1982; Nutter,

2006; Scott et al., 2002; Van Aarde, 1987). Often the kitties die before the 6 months, and the females have around 3 kittens per litter (Nutter, 2006).

Several studies have focused on diseases carried by free-roaming cats, that are often seen as a pest and also for presenting great importance in epidemiology and public health (Slater, 2001). Some of the zoonosis that are commonly found in free roaming cats are *Cryptosporidium spp., Giardia spp., Toxocara cati, Bartonella henselae* e *Toxoplasma gondii* (Nichol et al., 1981; Nutter, 2006). The transmission of diseases may occur by directly contact with the cats, or indirectly by contact with its droppings, with feeding spots maintained by cat colony caregivers also increasing the risk of diseases spread, especially toxoplasmosis (Hawkins et al., 2004). This disease is known to be transmitted by cats, contaminating the soil by spreading the oocysts. Other animals and plants might then be contaminated and finally transmit to humans if food is improperly prepared and consumed (Sah et al., 2019). Therefore, they may be especially problematic when close to public gardens, especially those used by children (Taetzsch et al., 2018). Recent reports on cats infected by the SARS-CoV-2 virus were published concluding that cat-to-cat transmission was observed, but cat-to-human is not yet confirmed (Opriessnig & Huang, 2020; Shi et al., 2020).

Moreover, cats are known to lower the diversity of vertebrates by zoonosis, predation or fear effect (Loss & Marra, 2017), they also can do that by influencing changes in the feeding or use of the space (Parsons et al., 2018). Birds and rodents diversity is hindered in parks (Loss & Marra, 2017) those also being the most prominent prey for cats (Tschanz et al., 2011). Cats are also known to reduce reptile populations in Australia (Woinarski et al., 2018). It was also observed that they may represent a threat to reintroduction efforts of mammals due to the predation (Hardman et al., 2016). Despite that, cats are also freed for the purpose of pest control, especially urban rats (*Rattus spp.*), however, cats prefer defenseless prey and there's no data that they can influence the density of large urban rats (>300) and therefore the benefit is inferior to the risk to the wildlife (Parsons et al., 2018). Thomas et al. (2014) suggests that an area of 300 to 400 meters buffer from important wildlife locations without cat ownership would be needed to mitigate the predation, however the behavior of the cats may be negatively affected by populational density, causing this value to increase.

The negative effects and animal-human conflicts associated with free-roaming cats require mitigation actions. Adoption is not an effective solution due to the overpopulation levels and the feral state of the animals. Most common solutions are euthanasia and Trap-Neuter-Release (TNR) programs. The TNR programs offer cats lower mortality rates, while being more efficient in population control in the long term, since it ceases their high reproductive capacity (Boone et al., 2019). Neutered cats also are shown to have a significatively longer lifespan than the intact counterparts (Nutter, 2006) as well as a smaller mortality rate for both

kittens and adults (Gunther et al., 2011). The models for neutering suggest the neutering each one or two years will help keep the colonies at a smaller number, however, for long term the colonies tend to recover due to immigration of intact individuals (Nutter, 2006). The non-neutered cats having the higher tendency to join groups of neutered animals, and the neutered are less likely to emigrate from the colony, proving the consistency of the TNR important (Gunther et al., 2011). Therefore, knowledge of those colonies may be helpful to create strategies to mitigate the problem in future intervention. However, only little is known about cat presence in green areas/parks, but there are NGO's dedicated to care for the animals. In 2019 some of the NGO's working in Porto metropolitan area got involved with TNR programs promoted by City Hall.

Normally, the home range of these animals are influenced by sex, the male's area being around three times larger than for females (Guttilla & Stapp, 2010a; Monterroso et al., 2009b). However, other study shows no such difference, except during matting seasons, where the young male were observed to use an larger area. A high overlapping rate, also occurs near the food sources, not having seasonal variation when the food resources are constant (Mirmovitch, 1995). The cats do show preference for areas that are more green rather than more urban areas in their distribution (Thomas et al., 2014). In Thomas et al. (2014) the max area used by the cat was far less than one square kilometers (7.55 ha), with an average of 3,41 ha, the daily average being 1,84 ha during daytime and 2,74 ha during night.

Portugal has a limited knowledge of free-roaming cats populations in urban environment (Gomes et al., 2017). In the city of Porto particularly, free-roaming cats are easily seen around in many places, but knowledge about the free-roaming cats numbers and colony structure still lacks. Gomes et al. (2017) observed three large areas in Porto for three years, identifying a small number of colonies, mostly occupying small areas with shelter and food availability.

This study aims to examine the structure, home range and the presence of colonies in urban areas in Porto, Portugal, as well as to verify if there is any interaction between neighbor colonies.

Material and methods

Study sites

The study sites were selected within the urban area of the city of Porto where the presence of free-roaming cat colonies was registered during the initial exploration period. Choice also took into account information's obtained from two NGO, Miacis and Animais de Rua, whose intervention is developed in the Porto metropolitan area.

The two selected sites have an area of around one square kilometer and include both residential and green environments (Figures 1 and 2). One of the study sites is located in the Bela Vista area and the other in the Falcão area.

In each study site several groups of free-roaming cats were identified.

In Bela Vista site five probable cat colonies were found (figure 2A and 3A):

- Saint Roque park (Park)
- Sport complex Monte Aventino (Aventino)
- João Espregueira Mendes street (Mendes)
- Fernando Moreira da Silva street (Silva)
- Antas street (Antas)

Saint Roque park and surroundings is a public park, open to public visitation from 8 am to 20 pm and pets are allowed in. It is a green area with an artificial lake. Trees, tall grass, tables, benches, openings in rocks that formed walls as well as a front porch of wood house are used by free-roaming cats as hiding spots, especially around the lake where humans have restricted access. A cat caregiver maintains multiple feeding spots for the cats.

The Sport complex Monte Aventino has several tennis courts and a restaurant. A line of trees that borders the back of the restaurant offers shelter opportunities and the restaurant staff refill regularly a feeding spot.

João Espregueira Mendes street it located at a residential area outside the walls of the Saint Roque park. Here we only identified vegetation as the main shelter available.

Fernando Moreira da Silva street is near a construction site in non-residential area. Most of the handout spots found are located in an area with difficult access to humans; they are in a fenced empty plot under an artificial cover and hidden by the vegetation.

Antas street is in a residential area, where no shelter or feeding spots were found.

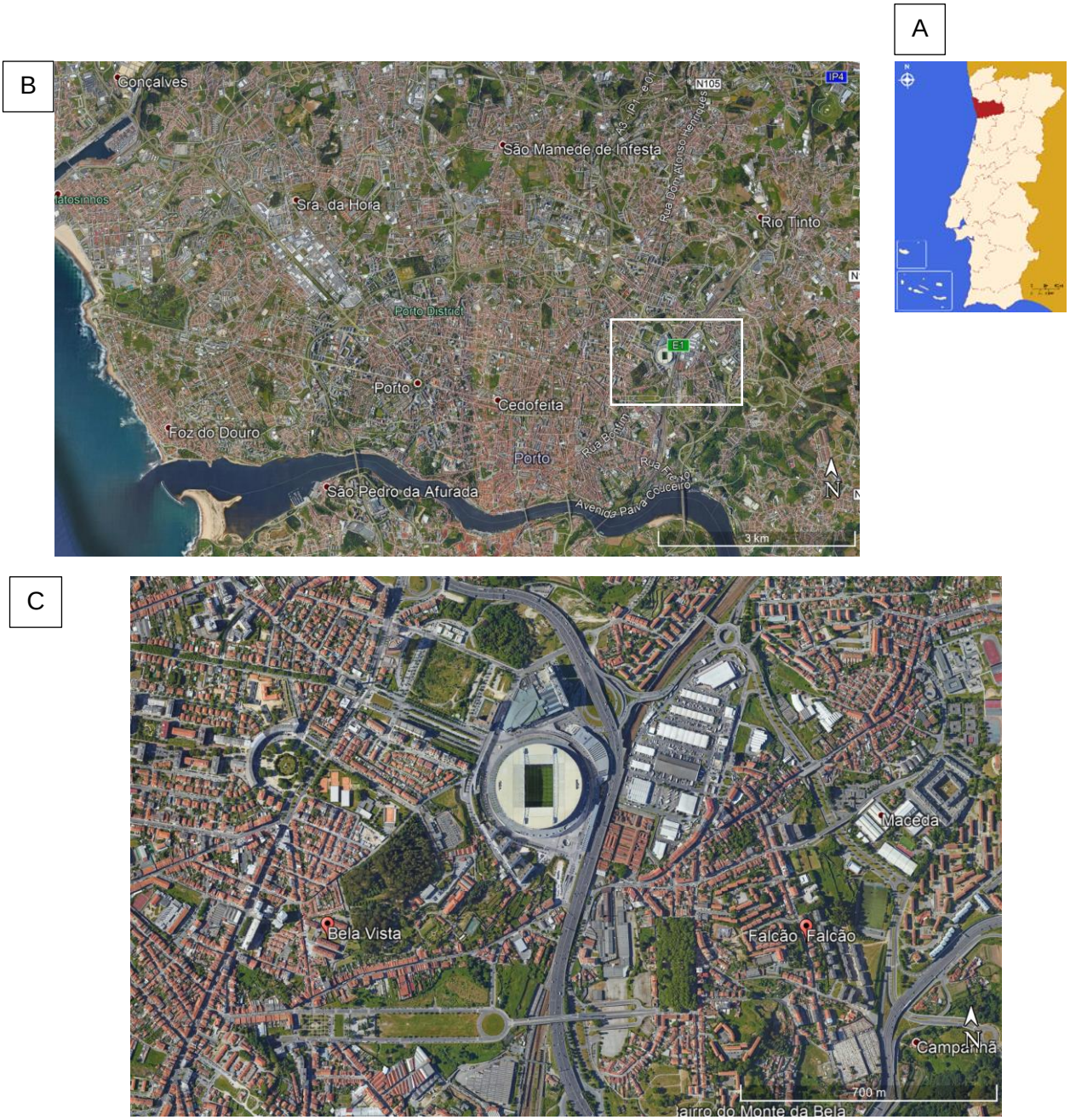

Figure 1. Study areas. A – Porto city (red) location in Portugal; B - The city of Porto with the indication of the zone where study areas are located (white square); C - Detail of the two select areas, Bela Vista (1) and Falcão (2).

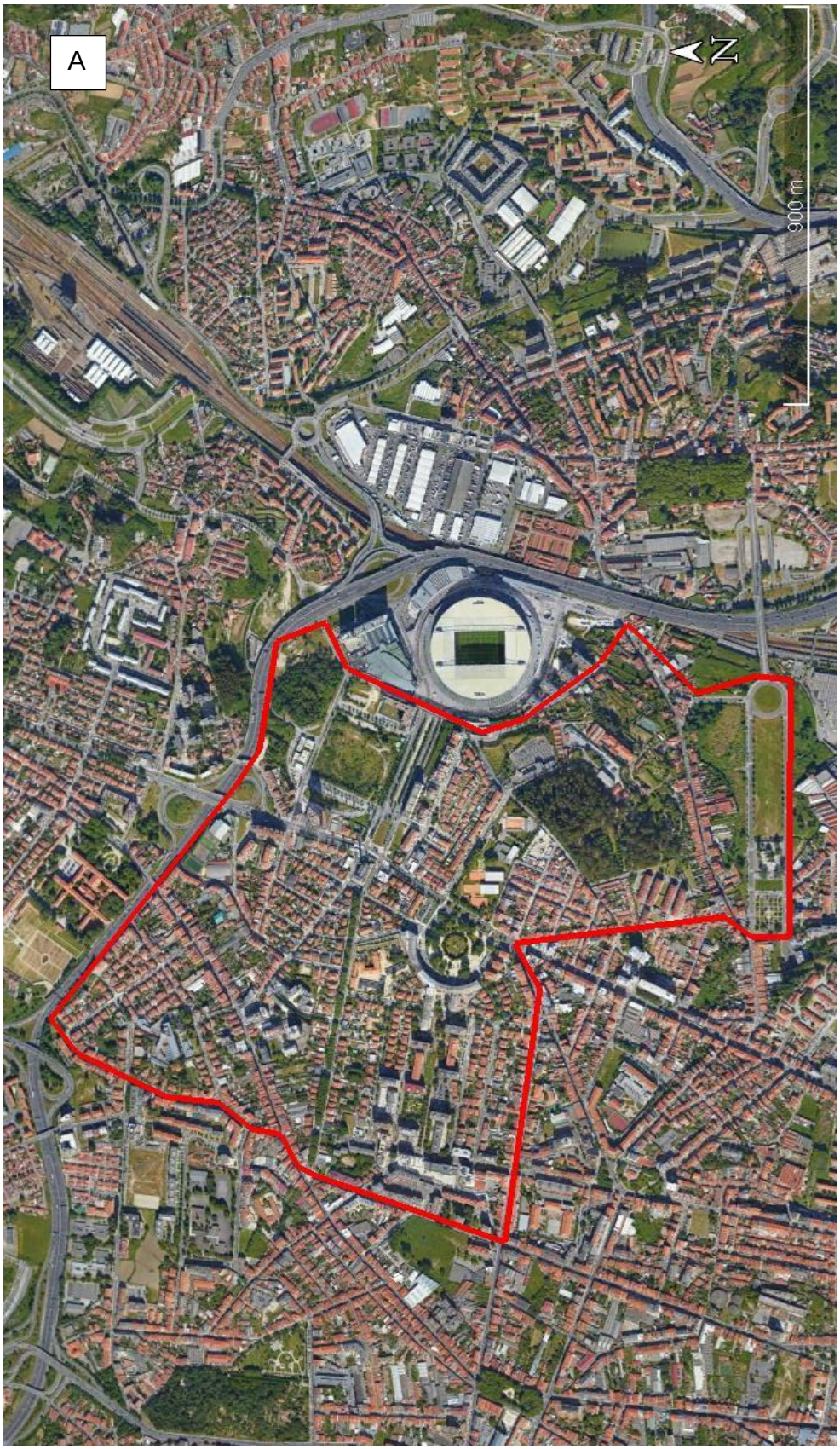

Figure 2. Sites where free-roaming cat colonies were searched for at the Bela Vista (A) and Falcão (B) study sites (the area scouted before the start of the study is marked in red).

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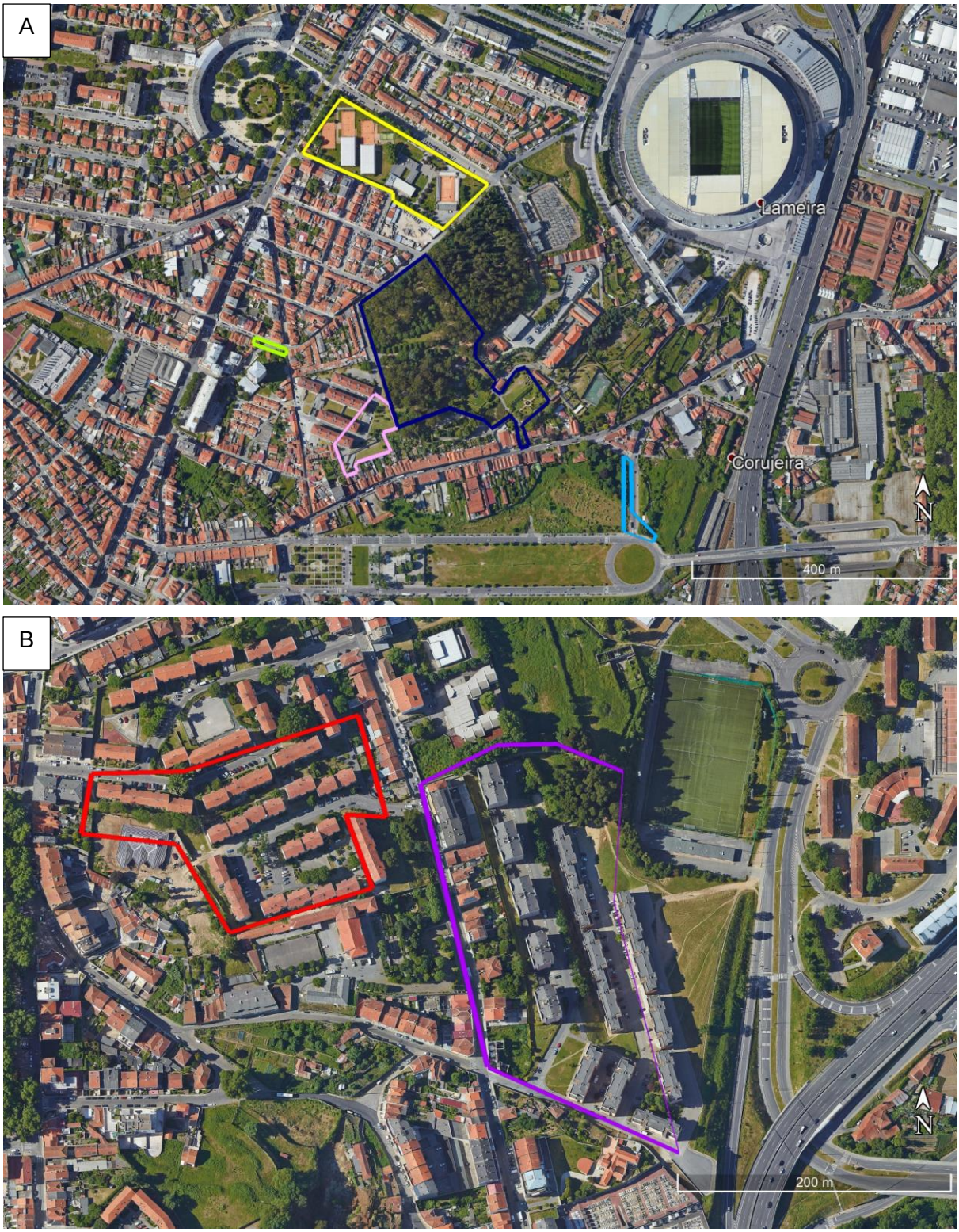


Figure 3. A- Bela Vista colonies locations: Park (Saint Roque park)- dark blue; :Silva (Fernando Moreira da Silva street) - light blue; Mendes (João Espregueira Mendes street)- pink; Aventino (Sport complex Monte Aventino)- yellow; Antas (Antas street)- green; B- Falcão colony locations: Casimiro (Maestro Raúl Casimiro street)- red; Oudinot (Cooperativa do Pego Negro street and Reinaldo Oudinot street)- purple.

In Falcão site three probable cat colonies were found at the following street proximity (figure 2B and 3B):

- Maestro Raúl Casimiro street (Casimiro)
- Cooperativa do Pego Negro street
- Reinaldo Oudinot street (Oudinot)

Maestro Raúl Casimiro street is a residential area with one feeding spot. However, during the studies public works started in January and extended until March. The main feeding spot previously available was moved to a nearby location. The residential quarter has several access ways that have a relative high presence of passing people. The main hideout for the free-roaming cats includes an enclosed area attached to the building and a frequently used artificial shelter.

Cooperativa do Pego Negro street and Reinaldo Oudinot street have feeding spots at the end of both streets. The feeding spot at the Cooperativa do Pego Negro street has an artificial shelter with grass, near a small garden; free-roaming cats can also use the vegetation and the fenced areas around as shelter. As both streets are dead end streets there are not major traffic that could place cats under the risk of being run over by cars. Car parked in these streets also give some shelter and protection to free-roaming cats, still offering risks to those animals.

Antas and Aventino colonies were excluded from this study. The first had too few animals, so they did not form a colony or the main location was not identified. The latter suffered an early interruption of data collection due to prohibition of photographic registration.

Data collection

Monthly monitoring visits to all presumed colonies identified occurred between August 2019 and March 2020 at three different periods; morning (9:00 a.m. to 1:00 p.m.), afternoon (2:00 p.m. to 6:00 p.m.) and night (8:00 p.m. to 00:00 a.m.). Morning and afternoon monitoring visits were made at least twice per month; however, at the Sport Complex Monte Aventino, that closes earlier, the night visit was not possible; furthermore, in December 2019 Sport complex owners forbidden further visits to photograph the cats. The night monitoring visits were made once per month in Maestro Raúl Casimiro street, Cooperativa do Pego Negro and Reinaldo Oudinot street with flashlight to allow minimal quality to the photos obtained. At Saint

Roque park a different approach was necessary as it was closed during the night. After permission was obtained in November 2019, two trap cameras (Bushell Trophy Cam 8 mega pixels and DTC-520v) were used. Both cameras can register color photos when there's enough light and have a nocturnal mode, that was the most utilized in this study. The first time they were installed, both were programmed to take three pictures during a 30 seconds period whenever triggered. From the second monthly session onwards, the cameras were programmed to take 30 second's videos whenever triggered, but a 30s cool down between videos was programmed. The equipment was placed without additional bait, instead it was located near established feeding spots (figure 4).

The length of the previewed study period was reduced due to the confinement imposed in March. After the end of the confinement period all colonies sites were visited twice (June and July) to appraise if new free-roaming cats were present. As in these visits the methodology referred to was not used the data obtained were not included in the analysis.

In each monitoring visit, an active search of free-roaming cats was done and all cats sighted were photographed with a Sony® DSC-hx400v camera providing an 50X zoom optics and GPS localization.

The photographs and videos were added to a database and used to identify the felines after the monitoring visits. The database also included cat geographic location, cat sex whenever possible to identify under direct observation. The presence of a collar, indicating that the animal is owned, or of a cut in the left ear, indicating that the animal was neutered, were also registered.

This procedure allowed to calculate the rate of re-sightings as well as discriminate individuals that were seen once or more times. It was also possible to identify cat presence along the study period (monthly and period – morning, afternoon and night-presence.

Moreover, two free-roaming cats (one female and one male) were equipped with radiotracking emissor (frequencies of 150.253 MHz) placed in a collar with an anti-chocking mechanism (using a commercial collar made for domestic cats) to avoid risks injury. Cat location was regularly searched using an ATS® model R400 receptor and a yagi type antenna. The collars were attached to the animals by a veterinary during the cat check-up necessary during a TNR procedure that occurred in October 2019 to the free-roaming cats at Saint Roque park leaded by the NGO "Miacis".

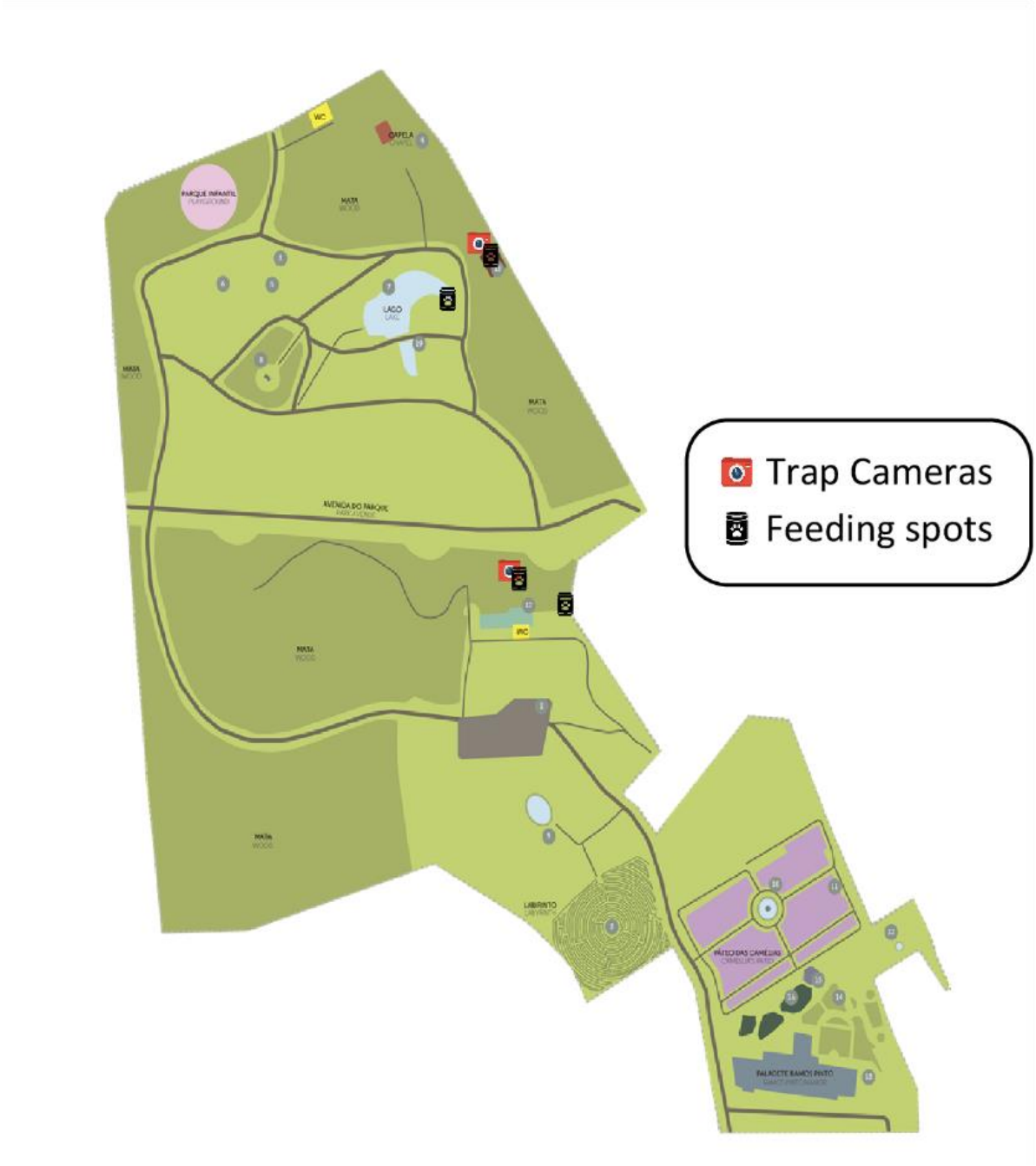


Figure 4. Saint Roque Park ground plan (Câmara Municipal do Porto 2014 - 2018).. Feeding spots and trap cameras placement sites are marked.

Home range estimation and statistical analyses

The coordinates of each cat sighting extracted from the photographs were added to a map of the city of Porto using ArcGIS (ESRI, 2019). With this tool, sighting points were grouped per individual, allowing to draw the minimum convex polygons representing the territory used by each individual free-roaming cat and later to estimate cat colony areas.

For statistical the Kruskal-Wallis method was used to compare the data from daily periods and month data (Tschanz et al., 2011). Comparisons between male and female and neutered and non-neutered was made with the Mann-Whitney U Test (McKnight & Najab, 2010). All statistic tests were done using IBM SPSS Statistics (Nie et al., 2019).

Home range estimations of felines are defined as the area where they find their shelter, food sources and reproduction. To determine such areas, the Kernel Density Estimation (KDE) (Signer & Balkenhol, 2015) was calculated from each cat GPS data. Two levels of KDE were estimated, the activity range (95%) and the activity range core (50%) for each feline. The user interface R Studio 1.3 with R statistics 4.0.3 software were used together with the reproducible home range (rhr) package (Signer & Balkenhol, 2015). The default bandwidth was implemented with maximum possible buffer. GPS data were extracted initially with EPSG:4326 angular data and converted in meters with meters squared as area with EPSG:3847. Cats with less than three GPS coordinates were not considered in this analysis.

Results and Discussion

Cat Numbers

More than 10.000 pictures were obtained and analyzed from a period of 8 months, that allowed to positively identify 150 different free-roaming cats. During the visits after the period of Covid-19 restrictions (June and July 2020) no additional cats were identified.

The number of cats belonging to the identified colonies (table 1), or colony size, is significatively different (P>0.05). The presence and number of feeding spots (Tennent & Downs, 2008b) as well as the environment the animals are found in (Thomas et al., 2014), could be factors that affected this disproportion, the areas did vary in both this variables.

Figure 5 gives a global view of the length of the periods along which each cat has been sighted. Only one female cat was sighted during every monitoring visit, but for all other cats number of sightings varied between 1 and 19. It presents moment that each cat was seen for the first time and when it stopped appearing in hopes to estimate the addition of new members or visitors to the colony as well as emigration or probable death or other factors, the last one not being possible to differentiate in most cases. It may help to identify the constancy of the population number in each colony, however, a longer monitoring period may be needed to exclude the animals that are only occasional visitors of the colony and may cause an over estimation of animals that were seen late or stopped being seen after a short period. The neuterization state being one of the factors that was found to affect the recruitment and emigration of the cats, where neutered cats less likely to leave the colony and non-neutered cats more likely to join neutered groups (Gunther et al., 2011).

Globally most cats were sighted a reduced number of times (1-5) along the study period (figure 6) and only a small number was sighted more than 15 times during the study period (Figure 6 and Table 2).

Table 1. Total area used by the cats in each colony; total number of cats and their sex, and percentage of adult and juvenile fractions.

Colony	Area used by each cat colony (m²)	Cats	Male	Female	Unknown sex	Adult %	Juvenile %
Park	26,706	37	18	17	2	86.5	13.5
Silva	6,137	14	3	1	10	57.1	42.9
Mendes	3,024	16	4	6	5	80.0	20.0
Casimiro	5,868	25	8	2	15	96.0	4.0
Oudinot	22,910	45	11	6	28	68.9	31.1

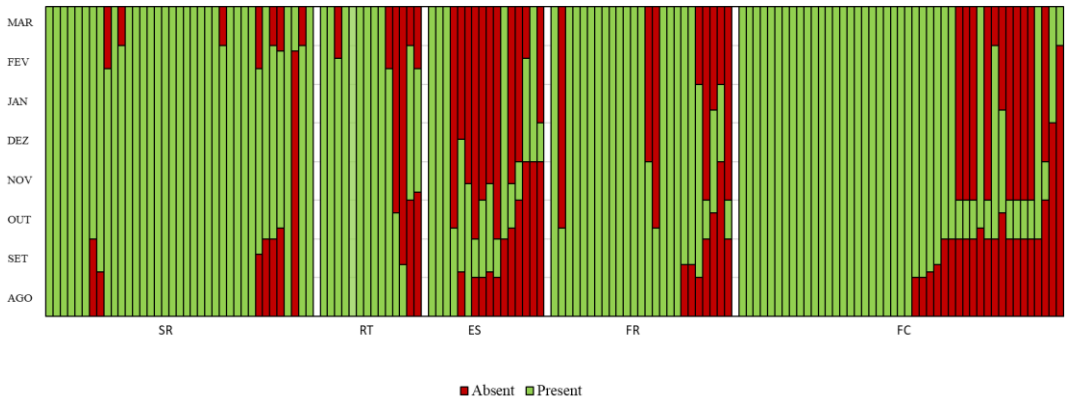


Figure 5. Absolute data on the frequency of sighting of each cat distributed by colony.

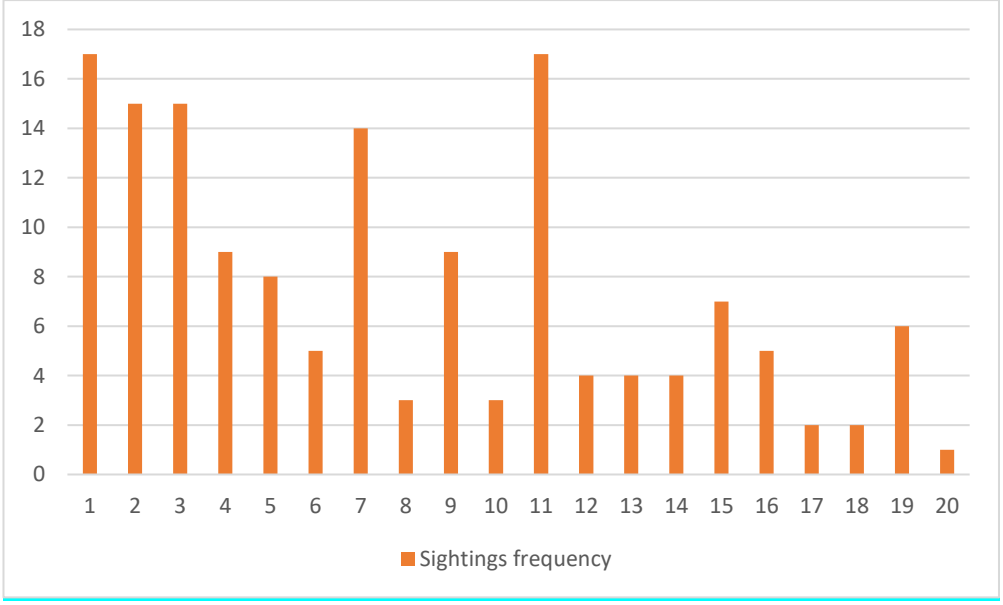


Figure 6 – cat sightings across the months and periods of the study

When each colony is considered the pattern is variable (table 2). The majority of colonies have a similar pattern, with cats being sighted a reduced number of times. For the Park colony most cats were sighted very frequently (67.5% sighted more than 10 times). For the Casimiro colony the pattern shows two groups of higher number of sighting.

Table 2 – Distribution of cat sightings in each colony

	Sightings distribution (%)			
	0-5	06-10	11-15	16-20
Park	13.51	18.92	35.14	32.43
Silva	42.86	42.86	14.29	0.00
Mendes	87.50	12.50	0.00	0.00
Casimiro	36.00	16.00	36.00	12.00
Oudinot	46.67	24.44	26.67	2.22
Aventino	60.00	40.00	0.00	0.00
Antas	100.00	0.00	0.00	0.00
Total	42.67	22.67	24.00	10.67

The results obtained for the Antas and Aventino colonies are not further analyzed; in the case of the Antas colony the reasons are the reduced number of cats identified and their very sporadic sightings; for the Aventino colony the reason was that monitoring was early interrupted due to the prohibition of photographic registration by the Sport complex responsible.

Sighting frequency

The analysis of the free-roaming cats observation frequencies show that there are significant statistical differences between colonies (figure 7; table 3). Park colony is different from all others as it has a higher sighting frequency average; no significant statistical differences exist between Silva and Mendes colonies, that are grouped because to the smallest frequency of cat sightings; the very small frequency of cat observations for the Mendes colony might have been influenced by the presence of physical barriers that restricted the capacity of observation. There aren't also significant statistical differences between

Casimiro and Oudinot colonies but the frequency of cat sightings is higher than the one of the Silva-Mendes colonies group.

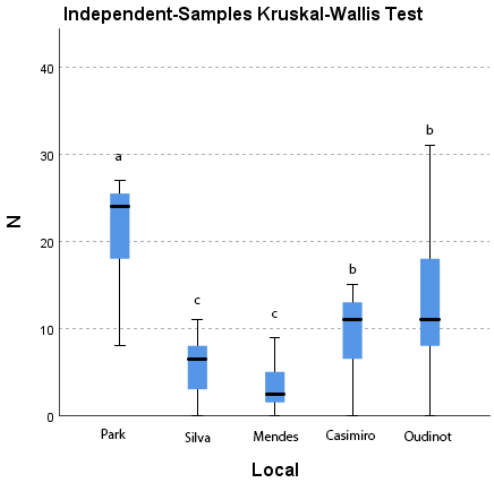


Figure 7. Frequency of observation of the animals related with the colony. N representing the absolute value. The different letters represent the difference between the means (N = 96; H= 48.65; $p < 0.05$).

Table 3. Pairwise Comparisons of each colony when compared the sightings frequency of the cats sightings ($p>0.05$).

Colônia	Park	Silva	Mendes	Casimiro	Oudinot
Park	-	-	-	-	-
Silva	0	-	-	-	-
Mendes	0	0.353	-	-	-
Casimiro	0	0.063	0.004	-	-
Oudinot	0.002	0.005	0	0.29	-

Cat sightings in all colonies is influenced by food availability. So, as all caregivers feeding spots are regularly replenished (twice a day for the Park, Silva and Oudinot colonies and at least once a day for Oudinot and Mendes) (See appendix 2) it is not surprising that the statistical analysis does not reveals significant statistical differences. The presence, quantity and consistency of replenishment of feeding spots were shown to influence the higher number of animals (Tennent & Downs, 2008b), sometimes being responsible for the presence of the colony (Carol Haspel & Calhoon, 1993).

Observation periods

Another factor that did not caused significant differences in colony structure and sightings frequency was the observation period (morning, afternoon or night) (figure 8) and the monthly evolution (August 2019 to March 2020) (Figure 8).

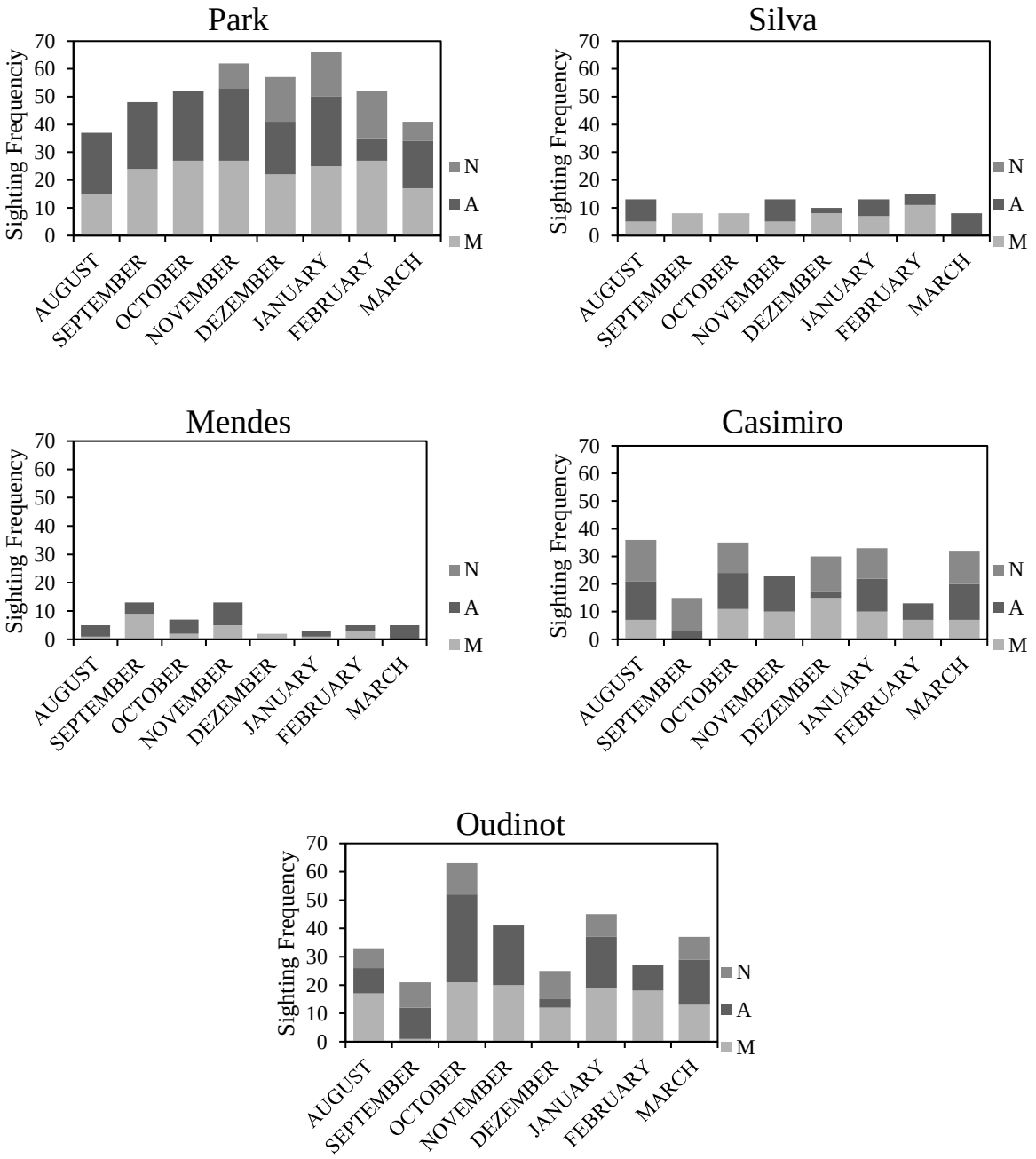


Figure 8. Sighting frequency of each colony by month and period. Park, also shows the nocturnal activity observed by the trap cameras and Casimiro and Oudinot are the only ones with direct nocturnal observation.

During the study period the number of cat sightings in each colony along time did not show any significant statistical variation (table 4). Furthermore, the number of cat sighting also did not revealed any significant statistical variation when the three daily periods are considered (table 4); only one exception was found concerning the Oudinot colony, were a significant statistical difference was obtained when comparing the morning (M) and afternoon (A) cat

numbers with the night (N) cat sightings (M-A – p=0.583; M-N- p=0.018; A-N- p=0.028). This data is consistent with the work of Mirmovitch (1995) that attributed this lack of variation to the consistency of food sources. The same seems to be occurring in the colonies studied since all the colony locations have at least one feeding spot that was regularly filled.

Table 4. Variation tests of the sittings across time and period (p>0.05)

Colony	Month	M-T	M-N	A-N
Park	0.209	0.368	-	-
Silva	0.995	0.304	-	-
Mendes	0.31	0.366	-	-
Casimiro	0.352		0.581	
Oudinot	0.513	0.583	0.018	0.028
Global	0.717		0.619	

The number of cats identified at Bela Vista and at Falcão areas is similar (Figure 9 and Table 1) but the number of cats belonging to each colony is variable.

Most of the observed animals were adults but at Silva and Oudinot the percentage of young cats was very high in relation to the effective number of animals (Table 1).

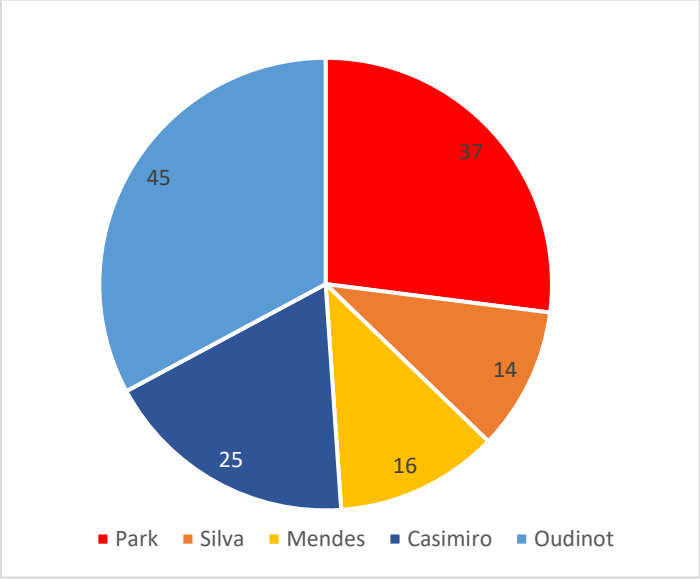


Figure 9. Proportion of cats found in the colonies studied in Bela Vista: Saint Roque park (Park), Fernando Moreira da Silva street (Silva), João Espregueira Mendes Street (Mendes); Falcão: Maestro Raúl Casimiro street (Casimiro), Cooperativa do Pego Negro and Reinaldo Oudinot streets (Oudinot).

The Park and Casimiro colonies are the largest, accounting for 60% of the number of identified cats (table 1; figure 9). This may be related to the type of environment that the colonies are at, as the cats were shown to prefer less disturbed environments and more green areas (Thomas et al., 2014).

The colonies Park, Silva, Casimiro and Oudinot had the largest frequency of multiple sightings (Table 2), most animals having been seen several times; Oudinot was also the colony with most single sightings (8 cats) while at the other colonies no more than 4 cats (in Mendes) were seen only once.

Sex ratio

Sex ratio is globally favorable to males (1♂:0.73♀) (table 1) and only at Mendes colony females outnumber males. The same was also reported in other studies (C. Haspel & Calhoon, 1989; Johnstone, 1987; Warner, 1985) without indicating any cause for this phenomenon. Only Johnstone (1987), that also found a male dominance, reported the effect of the wet seasonon the sex ratio of the litters; however Johnstone study was carried out in a subtropical climate, not at a region with temperate climate as the city of Porto.

TNR

Some TNR procedures were performed at both the study areas, Bela Vista and Falcão, prior to this study.

Park, Silva and Mendes colonies, in Bela Vista area had 5, 2 and 1 neutered cats at the beginning of the study. The non-neutered cats of the Park colony were neutered during a TNR procedure during September (figure 10 A), so all Park colony cats (n=37) were neutered.

At the Falcão area it was only possible to confirm that 12 cats (48%) of the Casimiro colony had been previously neutered; others four cats could also be neutered but the photographs taken did not allow to confirm it without any doubts. For the Oudinot cat colony, and at the beginning of the study, we clearly identified 3 neutered cats; in January 2020 (figure 10 B) all cats were trapped and neutered during the TNR procedure.

The TNR procedure, involving trapping, anesthesia and a surgical intervention, undoubtedly affect cat behavior, at least for a few days after de procedure. Such behavior changes, namely the stress resulting from trapping experience, might negatively result in a reduction of cat sightings during the period following the TNR procedure. For how long behavior changes persist is not known and it was not investigated in this study.

TNR procedures have been reported to results in the reduction of the number of cats per colony in Rome (16 to 32%) (Natoli et al., 2006b) but new individuals were observed after three years, coming from abandonment, resulting in a subsequent 21% increase. Therefore, educational measures are needed to maintain TNR effects. Porto city has recently implemented TNR activities, but success in colonies as Park and Oudinot is far from being evaluated. Therefore, we recommend these data to be reference for future follow up and to create strategies to avoid the increase of colony numbers by incoming non-neutered cats.

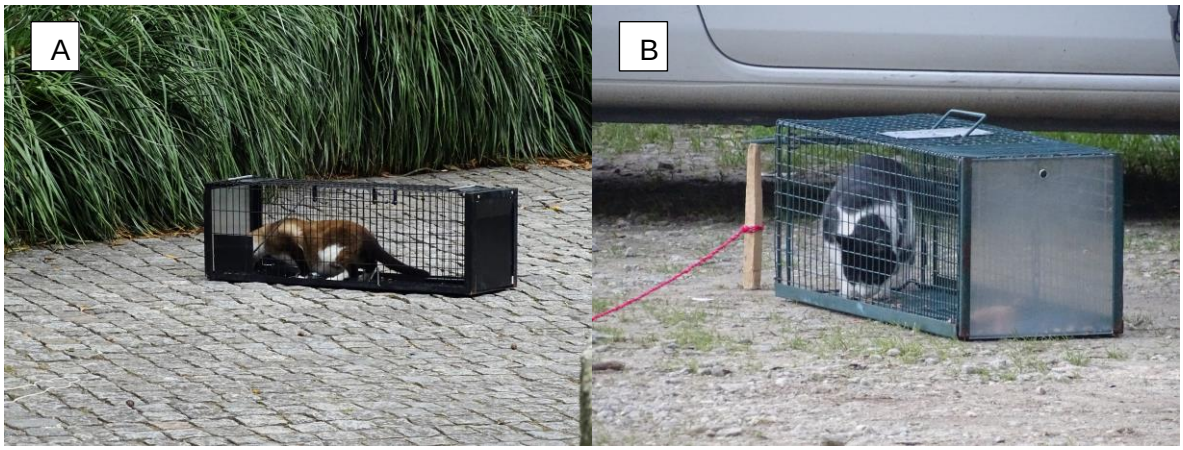


Figure 10. Cats trapped during the TNR procedures at the Park and Oudinot colonies.

Home range

Individual free-roaming cats home range is highly variable (table 5 and figure 11). Data shows that the cats tend to use small areas when compared to the total area used by all cats at the colonies. However at the Park and Oudinot colonies cat home ranges are much bigger than the remaining colonies observed in this study, probably due to lower disturbance factors.

Table 5 – Home range area means based on each cat of each colony.

Colony	Park	Silva	Mendes	Casimiro	Oudinot
N	37	14	15	25	44
Min (m^2)	1	25	5.32	1	1
Max (m^2)	10187	1201	1281.23	1387.62	8768.35
Mean (m^2)	4449.1	409.9	297.777	511.345	1972.232
Std. Dev. (m^2)	2460.22	442.15	369.2366	423.9895	2318.172

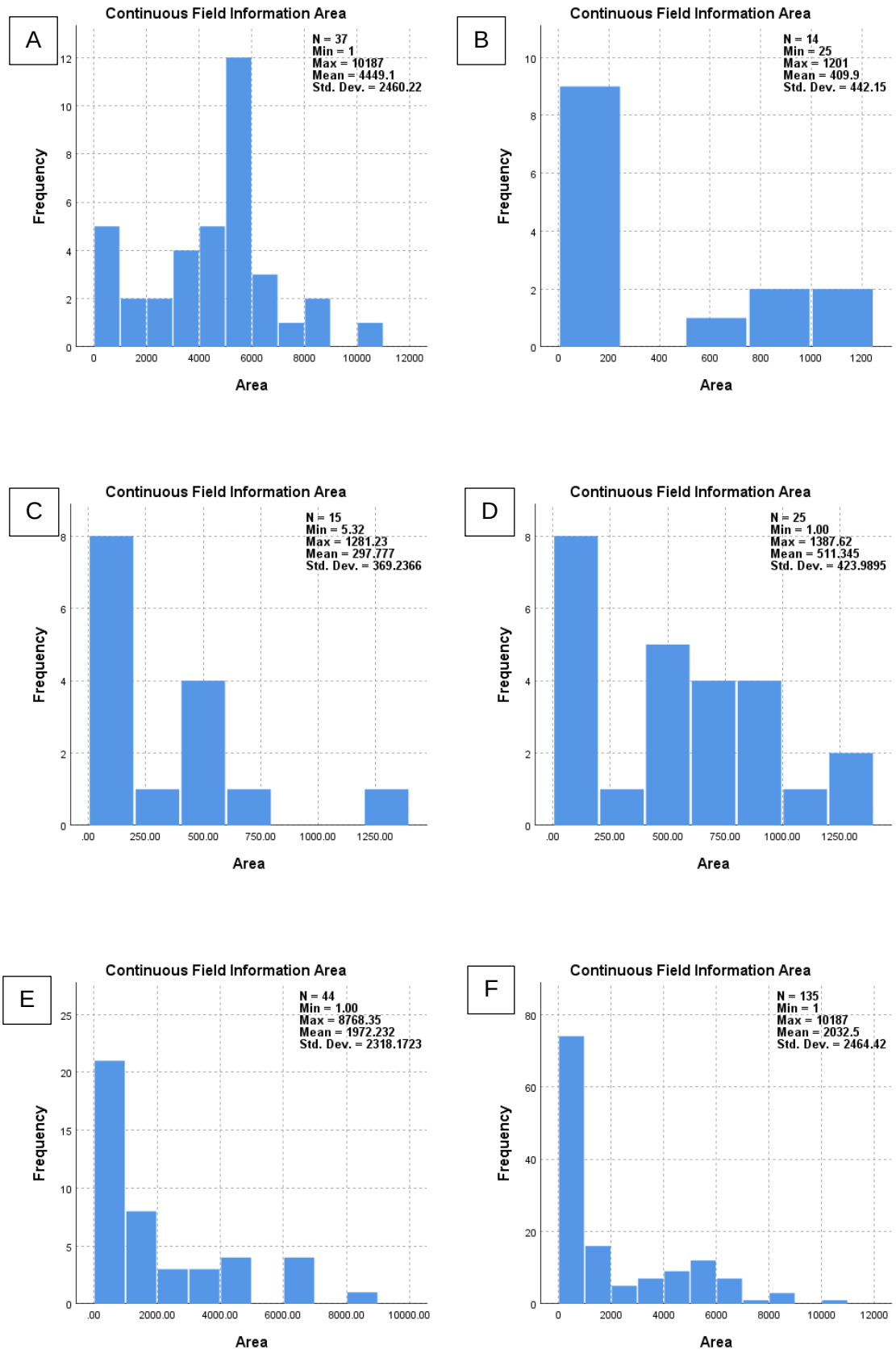


Figure 11 – Variation in the home range size observed at the Park (A), Silva (B), Mendes (C), Casimiro (D), Oudinot (E) colonies and globally (F).

The statistical analysis indicates that home range is not influenced by cat sex neither when considered globally nor considering each colonies (figure 12). Further analysis comparing neutered cats and non-neutered cats, whenever that is possible, showed no significant statistical differences in each colony, except for the global values ($p > 0.05$) (figure 13).

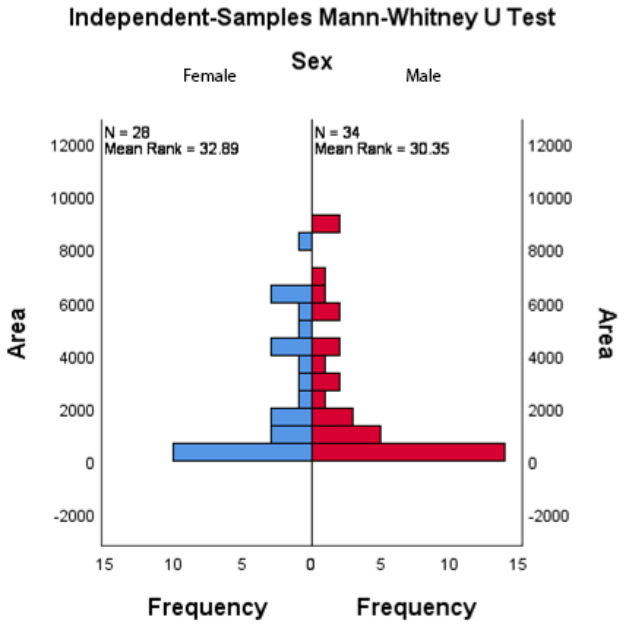


Figure 12. Comparison between the area size used by cats of different sex.

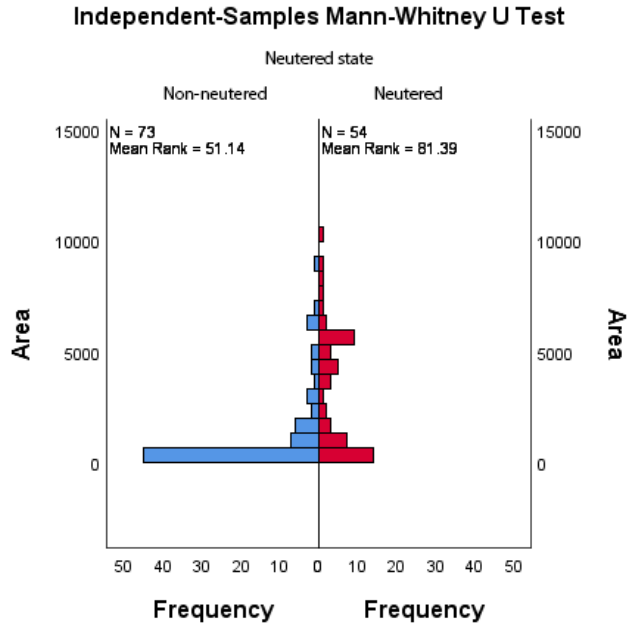


Figure 13. Comparison between the area size used by neutered and non-neutered cats.

In other urban cat colonies studied in other locations (Mirmovitch, 1995; Piccione et al., 2013), no seasonal frequency variation in animal sightings was also reported. In what concerns the monitoring period, it would be expected to do not find much cat activity during the dark hours (Delmar Cerutti et al., 2018), but some previous work showed that when anthropic handouts are delivered cats do adjust their rhythm of activity to the feeding supply (Piccione et al., 2013). It is possible that this is the reason of similar frequencies during periods and seasonality registered in this study, since handouts were constant across the year.

Oudinot and Casimiro colonies, at Falcão area, are very close to each other, the closest cat sightings from the two colonies being only 110 meters apart. However, they are separated by Falcão street, where traffic is intense all day, so contributing to colonies separation.

On the contrary, the Oudinot colony is located at two adjacent streets dead ends, so with limited traffic intensity. And although there is a feeding spot at the end of both streets, some cats were regularly sighted in both feeding spots and some others only in one of them; in spite of this we may only consider the existence of one colony in this zone.

Mendes and Silva colonies have the lowest number of cats, least sightings numbers and smallest area occupied. These colonies areas are the ones that are more largely subjected to human influence (buildings and traffic). The presence of cat colonies in such places is undoubtedly due to the maintenance of feeding spots (one for Mendes and four for Silva colonies). Furthermore, cats can easily move around in spite of some obstacles. However, Pillay et al. (2018) verified the preference of feral cats for more urban and anthropic areas, prioritizing private green (gardens, golf courses etc.) and open areas. It is possible that it has to do with the lower levels of disturbance.

The area used by the colonies is influenced by parameters related with colony characteristics (number of cats, cat sex, neutered/non-neutered cats) as well as habitat characteristics (number of feeding spots, feeding spots replenishing regularity) (Liberg et al., 2000; Mirmovitch, 1995; Tennent, 2005 Tennent & Downs, 2008b, Turner & Bateson, 2000; Warner, 1985).

Minimum convex polygons (MCP; Barratt, 1997) were used to estimate cat home range and their territory area. Most of the cats observed in the five colonies occupied a territory area inferior to a thousand square meters, regardless of sex and condition (neutered/non neutered) (figures 12 and 13). A similar observation was made at Randolph County (North Caroline, USA) (Nutter, 2006).

According to the data obtained there is a big overlapping of individual cat territories around the feeding spots (figure 14 A, B and C). Mirmovitch (1995) also noted that cats tend to have overlapping areas where the feeding spots are plentiful.

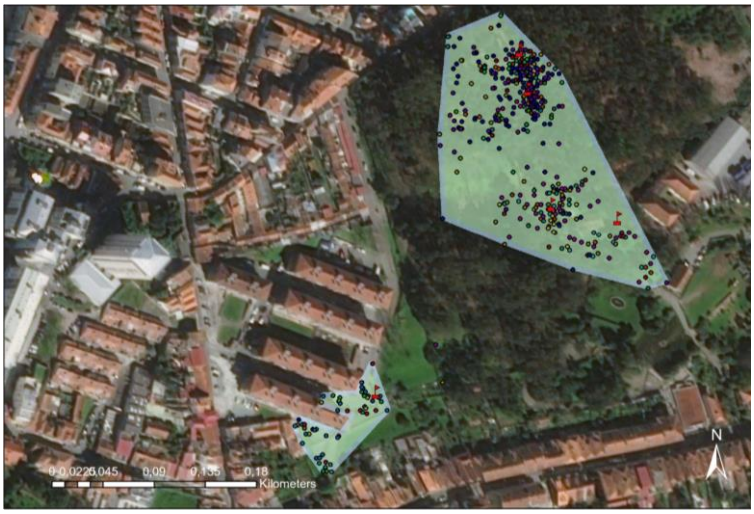
Park cat colony territory occupies the largest area of all colonies studied but with the lowest cat density (table 6). However, cat individual territory is smaller, where half of animals stays near one feeding spot and the other half frequents more than one spot, making larger displacements (figure 14 A and 15). Oudinot occupied the second larger colony area (figure 14 C), with similar density as Park's. However, Oudinot have the biggest number of animals, but with lower re-sightings when compared with Park. Individual activity range is the largest in Oudinot colony, but most of them shared the feeding spots available, dispersing more than Park. Smaller colonies (Mendes, Silva and Casimiro) have similar individual activity area, with no statistical difference among them (figure 14 A, B and C). Area restrictions may have resulted an increase in animal density (table 1).

It is known that in urban areas, the constant supply of food promotes colony formation with artificially high density, similarly to the observed in this study (Gomes et al., 2017; Laundré, 1977; Tennent & Downs, 2008a).

Table 6. Proportion of cats and area used by the colony as a whole.

Colony	Area (m^2)	N	N/m^2
Park	26,706	37	0.138547
Silva	6,137	14	0.228138
Mendes	3,024	16	0.529173
Casimiro	5,868	25	0.426042
Oudinot	22,910	45	0.196418

A



B

C

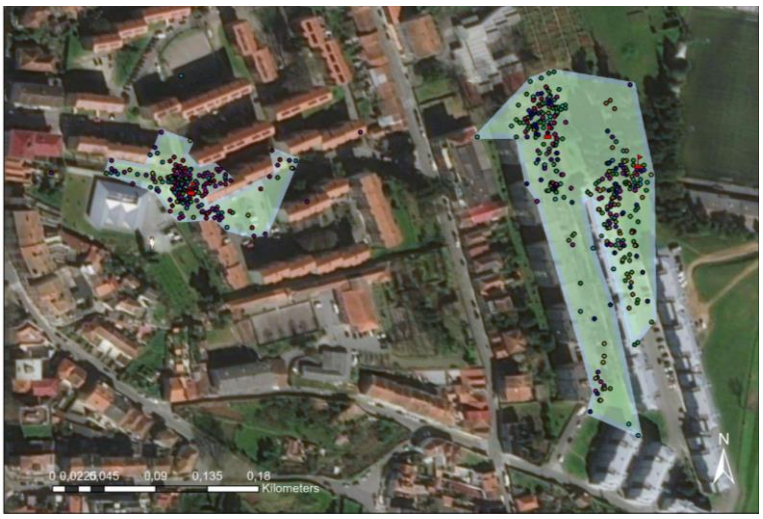


Figure 14. Colonies areas outlined. A- Park and Mendes; B- Silva; C- Casimiro and Oudinot. The flags indicate feeding spots, the dots show all cat sightings (different dot colors for different cats).

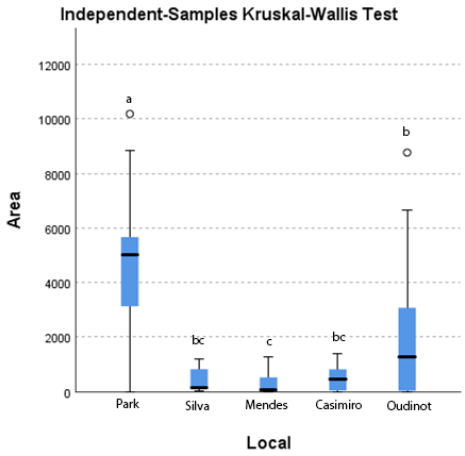


Figure 15. Area (in m^2) occupied by the colony cats. Letters indicate colonies grouping (N= 135; H= 46.91; p< 0.05).

Mean cat territory size for each colony, as obtained by KDE statistical analysis (table 7), points out to sizes that are smaller than it would be expected by a direct calculation of the total area cats use.

Table 7. KDE statistical data in squared meters for 50% (activity range core) and 95% (activity range).

Colony	KDE (50%) in m^2					
	Mean	Standard Deviation	Maximum	Minimum	Colony Area	Neutered/ non-neutered ratio
Park	2595.0	2285.7	11609.1	190.1	9607.6	1:0
Silva	1171.2	1263.6	4127.2	101.4	1190.6	1:5
Mendes	2139.7	1795.9	4701.1	58.3	2723.7	0:1
Casimiro	2334.4	2829.2	11151.7	560.8	2016.1	2:1
Oudinot	5664.7	5479.6	22669.7	257.8	5595.4	1:0
	KDE (95%) in m^2					
Park	12899.5	9687.2	40256.7	114.4	46121.9	1:0
Silva	4736.4	4789.5	15399.3	416.9	8978.6	1:5
Mendes	8320.1	6829.6	17001.8	239.9	10562.5	0:1
Casimiro	12276.1	17151.0	66706.8	2270.5	13838.1	2:1
Oudinot	29707.3	29906.4	107880.9	1299.4	32270.5	1:0

The largest individual mean activity ranges for individual felines are in Oudinot and Casimiro in both activities range and activity range core (See also appendix 1). Although Park has a large area available for the felines, most of the cats are grouped in a relatively small

area of activity range core. Areas between Park, Mendes and Silva are close possibly due physical movement limitations and most cats being neutered. Casimiro colony is also mostly neutered, but also have the largest standard deviation. Neutered cats in this colony occupy an area 25% lower than non-neutered cats, possibly contributing with increase in standard deviation.

Nutter (2006) verified that vasectomized males covered a larger area from feeding spots than neutered to search for non-neutered females, probably due to hormone levels reduction. There is not yet a consensus regarding the sensibility of animal density with sex and neutered, since in another paper, males areas were significantly larger than those of the females, with no influence due neuterization (Guttilla & Stapp, 2010b). Here, with TNR procedures during the study, it is difficult to reach to more precise conclusions. However, the available home range results may supply TNR programs with data for later evaluation of its effects, since 100% neuterization was accomplished in the Park and Oudinot colonies after the procedure.

Furthermore, most areas covered by cats are overlapping each other within colonies. Therefore, the mean area covered by each cat is near the area covered by most cats in a given colony. However, each individual may cover marginally different areas, resulting in differences between colony area and mean individual cat area. That is the case in Park and Oudinot colonies, although Oudinot's cats individually cover a larger area, Park colony's area is larger than Oudinot's. Studies made in other locations verified that neuterization increase cat's longevity and make them more attentive to feeding schedule, better adapting to anthropic relationship and benefiting more from feed access than non-neutered animals (Finkler et al., 2011). This can be one possible explanation for higher re-sightings rates in colonies with higher neutralization ratios, as well as grouping near feeding spots, increasing animal density.

The female cat with the radio-tracking collar (figure 16 A) showed a very small home range, never leaving the park or even distancing herself from the food source, where she was sighted, even without the aid of the collar, in every month and period of the study. The female collar was lost between March, 2019 and June, 2019 after the studies were interrupted due to Covid-19 restrictions. As for the male, its presence was confirmed after the TNR procedure by an observation made only once by both trap cameras in the same day (figure 16 B), showing a higher mobility. Unfortunately, afterwards the scarce data on its collar signal do not allow to further analysis its behavior, and in fact probably he lost its collar soon after the TNR procedure (figure 16 B).

Figure 16. The picture A shows the female with the collar and B shows the male. The first taken with the Sony® DSC-hx400v and second with trap camera.

Conclusions

The free-roaming cat colonies studied revealed to be different and the environmental conditions are important factors explaining the differences, namely the disturbance factor such as human behavior and food availability as well as city traffic. Cat condition, such as if they were neutered or not, and when the TNR procedures occurred might also be seen influencing colony size. Male cats are generally more abundant than females, but cat sex does not appear to influence cat colonies in the study area.

Most cats were seen only a few times, with exception of the ones found in the Saint Roque Park, where the low level of disturbance may be a great factor in the permanence of the animals in the colony. However monitoring might have been affected by the difficulty some inaccessible shelters placed to the observations and it is also possible that the flat or irregular terrain might also be factors affecting cat sighting.

TNR procedures are effective means to reduce population size in free roaming cats in the medium term, but impossible to report for the short duration of the study period. No significant statistical difference was found between neutered and non-neutered cats in what concerns territory range. Almost all cats have a very close relationship with food sources and food handouts were regularly place at the colonies feeding spots, so it is not surprising that no statistical significant difference was notices nor considering the daily periods, nor along the study period.

Feeding spot availability appears to be the main reason leading to the foundation and maintenance of cat colonies, being more decisive than sex, time of the year or period of observation time. This can be easily observed by animal's polygon positioning over the feeding spots, corroborated by the KDE analysis. TNR procedures were made during this study and had neutered 100% in Park and Oudinot colonies. These data may support future studies to research the consequences of the procedure in the population structure. KDE data suggest that neutered animals occupy less area than non-neutered ones.

A more wide study may be necessary to verify if the tendency found in this study are widespread in other colonies of Porto. However, the difficulty of sex identification may affect the sex ratio distribution analysis, animals with longer fur being harder to identify. However, there are no more efficient method known to date as the cats in the colonies usually don't allow approximation.

A continuous monitoring may be needed to better understand and verify the effectivity of the TNR in the two colonies that were targeted during the study.

The range of the territory of the cats may be underestimated in this study due to barriers that can be crossed by the animals, but can present access limitations (private and enclosed areas) that did not allowed their follow up during monitoring visits.

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Appendix 1

Table A1 – KDE's activity range (95%) and activity range core (50%) for each feline.

Colony	KDE (50%) in m^2	KDE (95%) in m^2
Mendes1	2415.944	8642.833
Mendes11	144.698	574.7312
Mendes13	4326.97	16450.16
Mendes14	3341.547	13893.7
Mendes2	4076.078	15333.66
Mendes3	2419.291	11400.76
Mendes4	4701.096	17001.84
Mendes5	58.34871	239.8999
Mendes6	1445.785	5648.57
Mendes8	414.5847	1596.717
Mendes9	192.7723	737.9348
Oudinot10	17502.73	96459.32
Oudinot11	8157.023	31767.2
Oudinot12	2062.149	7787.697
Oudinot13	9552.747	34825.11
Oudinot14	5842.091	27578.56
Oudinot15	511.1567	1813.523
Oudinot16	2888.43	106381.4
Oudinot18	4272.208	23876.91
Oudinot19	905.4704	4323.497
Oudinot2	504.5671	1766.226
Oudinot20	9138.455	53529.04
Oudinot22	7622.401	46419.82
Oudinot23	6575.82	35806.62
Oudinot24	10973.62	47916.6
Oudinot25	1667.277	8851.417
Oudinot26	1431.298	7012.279
Oudinot27	3379.789	22571.97
Oudinot28	9007.747	36496.76
Oudinot29	18103.21	66755.14

Oudinot3	2131.635	10561.79
Oudinot30	2925.729	11364.2
Oudinot31	3392.827	11676.38
Oudinot36	3285.986	11711.22
Oudinot38	9291.504	55258.36
Oudinot39	3273.208	12464.04
Oudinot4	5002.122	29161.2
Oudinot44	1357.934	5333.55
Oudinot46	1134.305	4413.239
Oudinot5	257.7867	1299.375
Oudinot6	4067.817	18382.17
Oudinot7	2381.167	9188.849
Oudinot9	22669.72	107880.9
Casimiro1	1391.19	7209.254
Casimiro10	1709.056	11510.09
Casimiro11	3833.552	22116.16
Casimiro12	743.5966	4482.414
Casimiro13	1597.129	8342.227
Casimiro14	578.0525	2270.521
Casimiro16	636.2087	2486.327
Casimiro17	830.0887	3262.535
Casimiro18	1166.877	4319.727
Casimiro19	2432.335	9483.301
Casimiro20	976.8812	3610.744
Casimiro21	634.1123	2380.383
Casimiro24	2259.07	8634.821
Casimiro3	1143.626	5979.746
Casimiro4	9052.476	53187.16
Casimiro5	1331.068	5869.868
Casimiro6	11151.67	66706.82
Casimiro7	3491.076	14788.61
Casimiro8	560.7649	2332.581
Casimiro9	1169.544	6548.499
Silva1	200.242	798.3158
Silva10	4127.184	15399.26

Silva11	739.8149	3393.43
Silva13	327.7458	1340.287
Silva14	101.3569	416.89
Silva2	2035.124	8140.744
Silva3	246.3212	1074.845
Silva4	2727.953	10007.44
Silva5	128.0439	578.4552
Silva6	332.6276	1276.425
Silva7	513.0369	2408.496
Silva8	1554.73	8045.049
Silva9	2191.905	8693.607
Park1	1907.299	10045.13
Park10	682.9347	4078.84
Park11	1129.04	6548.692
Park12	935.0095	6051.043
Park13	1124.996	5214.041
Park14	2310.377	12491.3
Park15	1399.171	8125.316
Park16	1086.389	6748.828
Park17	1149.522	6800.938
Park18	3172.118	13750.04
Park19	3591.753	19716.95
Park2	4273.426	21714.93
Park20	3248.611	17628.31
Park22	1945.419	8125.854
Park23	1488.274	9093.972
Park24	4626.969	27438.47
Park25	1402.851	8806.36
Park26	3244.879	16281.03
Park27	2053.608	9205.064
Park28	4805.485	26904.19
Park29	1237.72	7570.598
Park3	781.4163	5125.511
Park30	5465.504	24031.87
Park31	3309.809	13260.27

Park32	3866.48	23075.68
Park33	7398.668	35155.38
Park34	1857.958	8360.728
Park35	334.362	1523.209
Park39	1650.348	8299.973
Park4	190.1309	114.3918
Park40	4426.801	24761.47
Park5	1436.056	6803.908
Park6	1153.308	5176.307
Park7	530.3476	3196.118
Park9	11609.09	40256.73

Appendix 2

Figure A1. Feeding spots in the study colonies. From left to right and top to bottom; Park, Silva, Casimiro and Oudinot.

Appendix 3

Table A2 – Number of cats observed in each visit during the study period. (Morning- M; Afternoon- A; Night- N)

		Colonies cat observation count																				
Month	Day	Park			Oudinot			Casimiro			Silva			Mendes			Aventino			Antas		
		M	A	N	M	A	N	M	A	N	M	A	N	M	A	N	M	A	N	M	A	N
8.2019	7	8																				
	9	8			3			2												3		
	12		12									4			1							
	15		12*																			
	16	3	5								5	1		1	3			5				
	19				10	5		2	10													
	23				12			4*												2		
	26					4			7			6*			2							
	27						7			15												
	31	8	16*														2	1				
9.2019	8										3			3								
	9	10																		1		
	11				1												2					
	12		24*												4		3					
	16					11			3													
	25	23*									7*			7			4					
	30						9			12												
10.2019	8		18									2			2		5					
	9					19*			7													
	10				17			7*			7											
	11	25*												2			4					
	21				7	22*		7	10													
	22	16	18								6	6*			3		3	4				
	29						11			11												
11.2019	5		19			15			11			5			7			3				
	6	20			16			3			2			2			5					
	12		14			12			2			2			2			2				
	17	8									3			2								
	18			9	14			4														
	26		13			4			3			3			1			3				
	28	21			8*			4			1			2			4					
12.2019	2			12			9			12												
	4	13			9			12			6			1			4					
	5	14			8			8			2			1			2					
	15	16	19	5	3	3	2		2	3	2	2										
1.2020	2			14																		
	12		16			13*			8			5			2							
	13	21			15			8			7			1								
	17			5																		
	23	18			14*			2														
	24		17			9			9		6											

		Colonies cat observation count																				
Month	Day	Park			Oudinot			Casimiro			Silva			Mendes			Aventino			Antas		
		M	A	N	M	A	N	M	A	N	M	A	N	M	A	N	M	A	N	M	A	N
	28						8			11												
2.2020	3			16																		
	17			3																		
	18			7																		
	19	19			10						6*			3								
	20																					
	21		8			9			6			4			2							
	26	23			14			7			6											
3.2020	4			7																		
	7		10			9			8			4			2							
	10		15			13*			8			7			4							
	11	17*			13		8	7		12												

*The animals were spotted being fed.