Implications for biodiversity of predation by the domestic cat (*Felis catus*) in Nigeria.

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Declaration of original authorship:

I confirm that this is my own work and all materials used from other resources has been duly and completely acknowledged.

Theresa Azin Udofia. University of Reading. April 2022.

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Abstract

Domestic cats (*Felis catus*) are efficient hunters and kill large numbers of prey. Since they can attain very high population densities, they pose a great threat to biodiversity. Humans have lived in close association with cats in various forms, both feral and domestic, for a long period and different cultural beliefs and myths associated with cats have developed over time. Our understanding of cat hunting behaviour and people's attitudes of people is almost completely based on studies from the wealthier parts of the world (UK, USA, Canada, Australia, New Zealand), with no studies taking place through much of Africa or the wider tropics. To fill this knowledge gap, I a) conducted studies of attitudes of people from Nigeria towards cats, and later contrast them with attitudes held by people from the UK, or those who have migrated to either country, and b) I survey cat population densities, cat ranging behaviour, and cat predation rates in four areas of Lagos.

This study finds an interesting duality in attitudes of Nigerians towards cats as pet cats are generally considered with some affection, but I find effects of deep-rooted myths, with negative views of cats as being associated with magic, and there is high acceptability of eating cat meat. These views were not held by people from the UK. For some traits evidence of a change in strength of views as people migrate, becoming closer to local views. Both countries show positive attitudes towards methods for mitigating cat predation.

Densities of cats in the megacity of Lagos estimated from house-to-house surveys and line transect methods were 84-125 cats/km^2 and 196-294 cats/km^2 respectively. For owned cats this is at the lower end of estimates from published studies, largely from the global north. The cat population for Lagos (1171 km^2) is estimated to be in the range of 122,143-286,538 cats. The ranging behaviour of pet cats in Lagos was seen to be affected time of day (larger at night), cat sex (males roam further), and season (larger ranges in the dry season). The absolute mean maximum daily area ranged by a cat was 13.18 ha and home range (95% KDE) varied from 0.07 ha to 10.40 ha, similar to other published studies.

Estimated predation rates were higher in dry seasons, with the mean daily predation rates for the dry and wet seasons being 1.32 and 1.05 respectively. The mean annual predation rate of 412 prey/cat/year is high compared to previous studies and estimates of annual mortality caused by free-ranging domestic cats in Lagos is in the range of 50.3m-117.7m prey. Male cats killed more, and overall mammals are the most frequently returned prey, followed by birds, reptiles, invertebrates, and amphibians in rank order; prey types are like those recorded in other studies.

Together, these studies present the first steps in understanding the interplay between cats, their owners and the public as we consider the role of cats as urban predators.

Chapter 1: Introduction

Implications for biodiversity of predation by the domestic cat (Felis catus) in Nigeria

Domestic cats (*Felis catus*) are recognised as constituting one of the major threats to biodiversity (Courchamp et al. 1999) both on islands and on the mainland (George 2010) and they are mentioned as one of the most invasive predators by the IUCN (Lowe *et al*. 2000). Cats introduced to Islands by human settlers are known to have contributed significantly to the endangerment of native mammals, reptiles, and birds (Konecny 1987; Veitch, 2001; Tershy *et al*. 2002; Nogales *et al*. 2004; Sims *et al*. 2008; Medina *et al*. 2009 and 2011; Palmas et al. 2017) and has become a conservation issue as many prey species have been driven extinction by cat predation (Burbidge and Manly 2002, Mitchell *et al.* 2002; Barrio *et al*. 2010).

Much research effort has gone into the study of predation by domestic cats in countries like the UK, USA, New Zealand, Canada and Australia, while there have been very few or no studies at all in geographically substantial regions like South or Central America, Asia, or Africa. These regions are of particular interest as these include areas of significant conservation concern and are also regions of rapid population growth and urbanization, suggesting that domestic cats will become an increasing ecological threat. In Africa, research work on domestic cats has been completely neglected considering the strong focus on the rich wildlife in the continent (George 2010, Morling 2014). Only a few studies have been performed and these are only from South Africa (Van-Aarde 1980; Tennent and Downs 2008; Tennent et al. 2009; George 2010; Peter 2011; Morling 2014; Pillay *et al*. 2018) and nothing so far from West Africa.

By taking place in Nigeria, West Africa, this project fills a much-needed gap not only in our knowledge of the consequences of cat predation for biodiversity but also on salient issues of in-situ culture, people attitude towards cats and management preferences.

1.1 Origin of the domestic Cat and Worldwide Distribution

Domestic cat (*Felis catus*) interactions with mankind dates to some thousand years ago (Driscoll *et al.* 2007; O'Brien and Johnson 2007) and spread from an original domestication cluster in Egypt (Serpell. 1988; Randi and Ragni 1991; Driscoll *et al*. 2009) with very fast population growth rate to present-day population sizes (Denny and Dickman, 2010). In 2002 the domestic cat population *(Felis catus)* was estimated at just above 200 million worldwide (Clutton-Brock, 2002), and a 2009 study estimates the global domestic cat population at around 600 million (Driscoll *et al*. 2009), which positions it as the world's most numerous pet today.

Cats are often grouped into three main categories depending on their relationship with humans, where and how they live. Cats designated as 'domestic cats' are pet cats livings in close association with a household and completely catered for all its needs by its owner (Moodie, 1995; Dickman, 1996; Brickner 2003; George 2010). Cats designated as 'stray cats' are free roaming cats not owned by anyone and rely partly on human provision for survival, while free roaming cats not relying on humans for support are designated as 'feral cats' (Moodie, 1995). However, most literature uses the term feral cats to represent both stray and feral cats (George 2010).

In some countries, domestic cats are kept as pets and are well treated and catered for. For example, the UK is home to more than 10 million pet cats and in the region of 800,000 feral cats (Murray *et al.* 2010; Aeger et al. 2017) making them the prevalent mammalian predator and greatly outnumbering all others in combination (Harris *et al*. 1995; Battersby 2005, Hanmer *et al*. 2017). Blancher (2013) and Loss *et al.* (2013) estimate populations of 84 million and 8.5 million owned cats in USA and Canada respectively and argued that these numbers may be almost matched by populations of feral cats. Turner and Bateson (2000) estimated domestic cat populations in different countries (numbers in brackets being the human population of the respective countries): Australia 2.65 million (20.3 million); Italy 6.53 million (58.1 million); Japan 7.24 million (127.4 million); United Kingdom 7.76 million (60.4 million); France 8.4 million (60.6 million); and USA 56.09 million (295.7 million).

The history of the evolution, domestication and dispersion of cats globally provide an insight to the understanding of cats and their activities (Denny *et al*. 2010). It was suggested that the subspecies *Felis silvestris lybica* (the African wild cat) is the most likely ancestor of modern day cats rather than *F. silvestris silvestris* (the European wild cat) (Sepell 1994). The African wild cat is known for having a more docile disposition, living and foraging near human settlements (Coman and Brunner 1972; Van Aarde 1986; Tennent and Downs 2008). The analysis of mitochondrial DNA indicates the age of ancestral *F. silvestris* to be in the order of 230,000 years and puts the estimated age of the African wild cat ancestor of present day domestic cats at some 131 000 years (Denny *et al.* 2010).

Morris (1996) suggests that the domestication process began even earlier than 3500 years ago, and recent DNA studies confirms an early domestication starting point in the near east and that first associations with humans came with the development of agricultural villages (Driscoll et al. 2007; Denny and Dickman, 2010). The Romans are credited as being the foremost early transport agent for domestic cat introduction to most European nations as their empire expanded 2000 years ago (Driscoll et al. 2009), though argument exists that cat must have arrived in Britain earlier looking at possible evidence of their presence in Iron Age sites (Harcourt 1979; Smith and Hodgson 1994). European colonists thereafter introduced domestic cats to the rest of the world, either for predators of pests, or as pets (Dickman 1996; Coleman et al. 1997; Morling 2014).

1.2 Cats as a threat to biodiversity

Carnivorous mammals introduced by humans to new ecosystems have contributed substantially to biodiversity decline and extinction of vertebrates in these ecosystems (Iverson, 1978; Moors, 1985; Kirkpatrick and Rauzon, 1986; Towns et al. 1990; Lowe et al. 2000; Fitzgerald and Turner, 2000; Veitch, 2001; Kawakami and Higuchi, 2002; Nogales et al. 2004; Butchart et al. 2006; Davey et al. 2006; Baker et al. 2008, Morgan et al. 2009; George 2010; Medina et al. 2011; Doherty et al. 2016). Amongst these, domestic cats, a generalist and opportunistic predator by nature (Barratt 1997a; Thomas et al. 2012; Loyd et al. 2013; Hanmer et al. 2017; Dickman and Newsome, 2015), is addressed as one of the greatest threats to fauna biodiversity and conservation and has been highlighted in a number of papers (Churcher and Lawton, 1987; May 1988; Barratt, 1997b, 1998; Wood et al. 2003; Robertson 1998; Baker et al. 2005, 2008; Dauphine and Cooper, 2009; Van Heezik et al. 2010; Denny and Dickman, 2010; Medina et al. 2011; Thomas et al. 2012; Loyd et al. 2013, Dickman and Newsome 2015; Kitts-Morgan et al. 2015; Doherty et al. 2016 Hanmer et al. 2017). Cats adversely affect wildlife populations in different ways; directly through predation and indirectly through risk-aversion effects and other sub-lethal effects (George 2010; Bonnington, Evans and Gaston 2013; Bellard et al. 2016). Risk-aversion effects occurs when cats or other predators negatively affect prey behaviour and habitat utilization (Lima, 1987; Beckerman et al. 2007), with birds' populations significantly affected by risk-aversion by indirectly altering traits such as clutch size and survival (Lima 1987; George 2010). These sub-lethal effects alter the behaviour of prey as cats may disrupt prey foraging habits and thus influence their survival rates by their mere presence in local environments (Bonnington 2013, Evans 2013 and Gaston 2013). Cat predation pressure in most islands have put some restrictions on the movement and inhibition of some species. For example, on the Canary Islands, populations of small Procellariiformes species are restricted to uninhabited Islets and isolated cliffs (Martin et al. 1989) and may likely experience a decline in population sizes than ever expected (Rando 2003). Additionally, it has been suggested that other indirect effects of cats such as disease transmission and competition with indigenous predators may in some circumstances have also have considerable consequences for prey populations (Paton 1993; Tidemann 1994; Dickman 1996; McCarthy 2005; Preisser et al. 2005; George 2010).

The introduction of domestic cats to many of the world's oceanic Islands by humans dates back to as early as 9000 years ago (Driscoll et al. 2007) and has established feral populations on most habitat (Ebenhard, 1988; Blackburn et al. 2004; Hilton and Cuthbert 2010), causing extinction of many birds, mammals and reptile species due to predation. The mortality level of birds in islands because of predation by cats is particularly striking, with approximately 33% of all known extinctions of native island-breeding birds being caused by cats (Lever 1994). The classic example is of Lyall's wren from Stephens Island, New Zealand. This species went extinct due to predation by domestic cats, and particularly a single cat named Tibbles introduced by the lighthouse keepers (Dickman 1996; Galbreath and Brown, 2004; Marra and Santella 2016). Medina and Nogales (2009) assessed the impact of feral cats in the Canary Islands on endangered species by evaluating their relative abundance in the cat's diet and taking into consideration their recent conservation status. The study indicated that sixty-eight different prey species were identified which included five mammals, 16 birds, 15 reptiles and 32 invertebrate species of which one endemic bird (*Saxicola dacotiqe*) and three endemic giant lizards (*Gallotia simonyi, G. intermedia and G. gomerana*) were considered threatened by the IUCN. Doherty *et al.* (2016) also documents that cat introduced to islands have caused the extinction of 63 animal species, including 40 bird species. Similarly, it has been recorded that *Felis catus* exact a huge toll on small birds and mammals (Denny and Dickman, 2010) and adult birds which make their nests on the ground suffer predation by cats while brooding eggs or provisioning chicks (Dickman, 1996; Galbreath and Brown, 2004; Bonnaud et al. 2007, Matias and Catry 2008; Marra and Santella 2016).

A study assessed feral cat predation in one of the World's key biodiversity hotspots, the New Caledonian archipelago (Palmas et al. 2017). They looked at the magnitude of cat predation for endemic wildlife found all over this unique natural ecosystem. More than 5300 cat scats samples were analysed gotten from 14 chosen sites which represent the 4 major natural habitats studied, over a period of between 4 and 6 years. This study recorded that feral cat's prey intensely upon flying foxes, petrels and squamates. Cat prey included at least 44 native vertebrate species of which 20 are in IUCN red-listed threatened species. Their study further added up to 44.4% species to the number of IUCN threatened species vulnerable to and being preyed upon by feral cats on the world's islands. Although this island represents only 0.12% of world's island area, it is home to 30.8% of IUCN threatened species known to be predated by feral cats. Management and conservation strategies such as cat eradication and habitat protection should be considered to salvage the situation of feral cat predation on this island (Palmas et al. 2017).

Cat predation activities on the mainland have equally been considered to be negative to biodiversity because of their high population density. In their seminal paper, Churcher and Lawton (1987) found that cat predation of house sparrows (*Passer domesticus*) killed a third of their population in a village in Oxfordshire, UK, and house sparrows' population are thought to be reduced by almost 60% in urban areas due to cat predation (Robinson et al. 2005). There is a correlation between cat densities and population of some breeding bird's species in urban environment in the UK, notably in the species that are susceptible to cat predation (Sims et al. 2008). A five month study in the UK revealed that an estimated number of about 9 million cats were involved in killing approximately 92 million vertebrate preys (Woods et al. 2003). Woods et al. (2003) based their estimate on the proportion of cats bringing home at least one prey item and indicates the prey of UK cats will possibly be in the range of (85-100) million prey items comprising possible distribution of (52-63) million mammals, (25-29) million birds and (4-6) million reptiles and amphibians. More recent work in Reading, UK showed a highly variable rate of prey returned rates across the seasons and estimation based on these rates gave a mean predation rate of 18.3 prey cat^{-1} $year^{-1}$ for these urban cats (Thomas et al. 2012) and it was noted that this varied remarkably both spatially and temporally. In total this paper estimated that over 180 million preys were killed, while more recent work (Pirie et al. 2022) in the same area suggests that this number could reach over 250 million prey per year in Britain.

It is worth noting that calculation based on cats' returns are very conservative and estimates of cat predation rely on estimates of prey not returned, but instead include estimates of the rates of prey consumed or left elsewhere. Results from recent studies on cat predation using mini-cameras to capture cat activity (Loyd et al. 2013; Morling 2014) reveals that previous studies that relied on records of prey items returned home by cats may have extensively miscalculated the capture rates of domestic cats. One of these studies in USA records shows that only 23% of prey items were returned home, while 49% and 28% were left at site and eaten at site respectively (Loyd et al. 2013). Reviews along this line suggest domestic cat predation levels in USA to be of between approximately 1-4 billion birds and 7-21 billion mammals per year (Loss et al. 2013).

Mead (1982) ascribed 31% of recoveries of ringed robins and dunnocks to cat predation but believed that there was no evidence that cats affected the overall populations of these species. Sharing this view, Fitzgerald (1988) and Fitzgerald and Turner (2000) asserted that on continental landmasses, wildlife had co-evolved with cats for hundreds of generations and that any species that were susceptible to predation would be 'long extinct'. It has also been argued that in many situations cats may limit populations of other predators, such as rats *Rattus* spp. that could have a more pronounced effect on wildlife (Fitzgerald, 1990; Fitzgerald, Karl and Veitch, 1991). Other studies suggest that bird predation rates in urban areas can be greater than reproductive rates, such that urban areas become sinks for bird populations (Thomas et al. 2012). Indeed, given the rapid growth in human populations and associated growth in domestic cat numbers, it is unlikely that all species susceptible to predation would be 'long extinct' but rather than more species are being affected by cat predation, rather than just species who are already diminished in numbers or excluded from regions.

Nevertheless, based on the high proportion of cats and the perceived serious impact on biodiversity (Baker et al. 2008; Sims et al. 2008; Morgan et al. 2009; Hanmer et al. 2017), cats are seen to be destructive, and despite the relative poor conclusive and authentic evidence to prove, these concerns has brought to fore the issues of management control measures and has led to wildlife conservationist and environmentalists pushing for implementation of management strategies to reduce the effects of cat predation as a precautionary measure (Lilith et al. 2006; Calver et al. 2011; Thomas et al. 2012). As part of management control, it has been suggested that feral cats should be eradicated from all oceanic islands as they have been from El Hierro Island (Silva and Mateo 2003) and La Gomera Island (Mateo 2001, Rando 2005). Also, non-native species eradication should also be taken into consideration (Courchamp et al. 2003, Taylor 2000). In addition, educational campaigns should be carried out to educate the people of the problem caused by the release of pet cats into natural habitats (Medina and Nogales 2009). To reduce predation or rate of returns, it has been suggested that cats should wear collar bells (Wood et al. 2003) or bibs (Calver et al. 2007), or sonic devices could be utilised (Nelson et al. 2005).

1.3 Cat Density

Cat predation and the possible risk posed by it to biodiversity has been highlighted and well documented over time (Baker et al. 2008; Bonnaud et al. 2011; Loyd et al. 2013; Blancher 2013; Thomas et al. 2014) and there is increasing recognition of the role of free roaming cats on the environment (Loss et al. 2013; Elizondo and Loss 2016). Reliable cat population density estimates are hence essential in managing cat populations and for working from an informed perspective in tackling cat population management issues (Schmidt et al 2007; Thomas et al. 2014; Elizondo and Loss 2016).

The global cat population size was estimated in 2002 to exceed just above 200 million (Clutton-Brock, 2002) and in 2009 a study estimated the global domestic cat population at around 600 million (Driscoll et al. 2009). In USA and Great Britain, cat densities recorded in studies into urban bird predation shows a range in the region of 229-523 cats/km^2 (Baker et al. 2008; Loss et al. 2013) in the UK and USA. The density of domestic cats is not dependent on the availability of prey to meet their energy needs because their owners provide them with the necessary requirements (Beckerman et al. 2007; Sims et al. 2008; Thomas et al. 2012) and this in increased by improved socioeconomic position (Murray et al. 2010). Indeed, the population density of cats could be exceptionally high in some urban areas and studies have found ranges of up to 2000 cats/km^2 (Liberg et al. 2000; Sims et al. 2008; Baker et al. 2010; Thomas et al. 2012). Consequently, cat population density has the propensity to reach levels which is considerably more than the normal carrying capacity of their ecosystem (Beckerman et al. 2007; Thomas et al. 2012).

Randomly sampled results from approximately 3000 households in the UK in 2007 showed that 26 per cent of the households owned at least one cat, 29.3% owned two cats and some 7.2% with three cats and those with gardens (97.6%) were more likely to own cats likewise those in semi-urban and rural households and with an ownership pattern that futures female’s ownership (70%) (Murray et al. 2010).

Studies in two areas in Baltimore USA in which 430 households were sampled revealed a significant difference in the ownership of cats between ethnic groups. In general, 29.9% of white households owned a mean number of 1.9 cats per cat-owning household, while 6.8% of black households owned a mean of 1.0 cat per cat-owning household. The densities of owned free-ranging cats for the two areas sampled were estimated to be 7.0 and 2.8 cats per hectare respectively (Childs 2015). This work suggests that studies generalised from limited areas are unlikely to provide accurate insights into cat ownership rates. Overall, it is very important to have a dependable estimate of the cat population which will benefit people working within the animal health and welfare professions, biodiversity conservationists and veterinary pharmaceutical companies (Murray et al. 2014).

1.4 Cat Ranging Patterns

Pet cat densities do not reflect the availability and density of their prey but rather housing densities and socioeconomic status (Sims et al. 2008; Murray et al. 2010). Studies have shown that even with regular access to human supplied food resources, the hunting behaviour of cats continues (Adamec 1976; Turner and Meister 1988; Kitts-Morgan et al. 2015). A review of Web of Science using the keywords *'Felis catus'* and 'ranging' uncovered few studies focused on the ranging behaviour of cats (whether owned or unowned) (Liberg 1980; Roger 1981; Apps 1986; Page et al. 1992; Mirmovitch 1995; Barratt 1997; Barratt 1997a; Meek ,2003; Morgan et al.2009; George, 2010; Van Heezik *et al*. 2010; Horn *et al*. 2011; Thomas *et al*. 2012; Moon *et al.* 2013; Thomas *et al.* 2014; Kitts-Morgan *et al*. 2015; Hanmer *et al.* 2017; Pirie et al. 2022).

As urbanization grows in both developed and developing countries with today more than half of the world population residing in cities, and numbers expected to double by 2050 (Runde 2015), issues of cat predation will increase, particularly in residential developments near areas of biodiversity value (Goddard et al. 2009). However, ascertaining the degree of effect domestic cats have on wildlife populations in urban settings remains uncertain (Crooks and Soule 1999; Lilith et al. 2010; Thomas et al. 2012). Understanding the ranging characteristics of individual cats is critical when trying to understand their impact on biodiversity (Thomas et al. 2014; Dickman and Newsome 2015; Hanmer et al. 2017), as understanding where they hunt will provide insights into prey at risk. Home range has generally been accepted to imply an area usually covered by animal in its normal routines of foraging, resting and reproducing. This concept of the animal home range is based on Burt's (1943) definition, and although irregular long-distance movements may occur these are not always considered as part of the animal's home range. In the case of unconfined pet cats which are also usually housed and catered for by the owners, their home becomes the focal point in their ranging patterns.

Studies on the home range of pet cats are few and have been criticised (Schmutz and White 1990; Baker et al. 2005; 2008; Thomas et al 2014; McDonald et al. 2015). In developed countries like the USA, Australia, New Zealand and the UK, the ranging behaviour of pet and feral cats has been studied using a range of techniques (Table 1).

Table 1. Mean ranging area (95% Minimum convex polygon analysis (MCP) and maximum ranging area (MRA, 100% MCP) shown for studies of urban cat ranging behaviour and factors affecting their ranging behaviour. Where {m} means Male and {F} means Female.

Source of information	Study area	Duration of time used	Method Used	Proportion of cats	neutered	Sex	Mean RA 95% (Range)	Mean MRA (Range)	owned/ unowned	Urbanization/Habitat	Day / Night	Season
Liberg, 1980	Southern Sweden	12 months	Radio-telemetry	55-72	NS	S			Both	N/A	Nill	NS
Barratt,1997	Canberra, Austrlia	9 months	Radio-telemetry	10	NS	NS	5.31(0.02-27.93)	8.58 (0.02-43.56)	Nill	S	S	NS
Meek,2003	Bherwerre Peninsula, NSW, Australia	16 nights	Radio-telemetry	14	NS	NS	Nill	2.92 (0.04-14.65)	Both	Yes	Yes	Nill
Kays and De Wan, 2004	Albany, USA	4 month	Radio-telemetry	11		Nill	0.24 (0.0061-1.3)	0.65 (0.13-3.0)			Nill	Nill
Morgan et al.2009	Christchurch, New Zealand	12 months	Radio-telemetry	21	NS	NS	Nill	1.8 (0.1-10)			Nill	NS
Van Heezik et al.2010	Dunedin, New Zealand	6 days	GPS	32		NS	Nill	3.2 (0.48-21.5)			NS	Nill
Metsers *et al*. 2010	Canterbury, New Zealand	10 days	GPS	38			Nill	26 (3-72)				Nill
Guttilla and Stapp, 2010	Catalina, California, USA	29 months	Radio-telemetry	142	NS	Nill				Nill	Nill	NS
Horn et al., 2011	Champaign-Urbana, Illinois, USA	15 months	Radio-telemetry & Collar mounted	42	NS	NS	({m}1.83)&({F}1.92)({M}157.01)&({F}56.59)		Both	Nill	Yes	Yes
Thomas et al. 2014	Reading, UK	2 months	GPS	20		NS	1.94(0.99-4.23)	6.88(1.69-11.15)	Both	Yes	S	NS
Hanmer et al. 2017	Reading, UK	months	GPS	38	NS	NS	1.94(0.99-4.23)	0.23(50KDE)	Both	Yes	S	Yes
Pirie et al 2022	Berkshire & Hampshire, UK	1 year	GPS	79			2.01	669.9/6.23		Yes	Yes	Yes

There were significant differences in the range sizes between cats roaming in the day and night. Cats from the same colony or household show overlap in core ranging area (Barratt, 1997; Thomas et al. 2014; Kitts-Morgan et al. 2015). Wood et al. (2003) showed that the number of mammals brought home per cat was significantly lower when they were confined at night. The home range sizes of unowned cats are larger than those of owned cats (Horn et al. 2011), and the range areas of suburban cats are larger than those of farmland cats (Barratt, 1997). The sex of the cat is seen to also affect the home range with feral male cats having larger home ranges than their female counterparts (Guttilla and Stapp, 2010, Horn et al. 2011, Gehrt et al. 2013; Kitts-Morgan et al. 2015), while sterilized male and female cats have similar-sized home ranges (Barratt, 1997). Unowned cats have the potential to affect biodiversity more than owned cats as owned cats show lower levels of activity than unowned cats throughout the year (Horn et al 2011). Kitts-Morgan et al. (2015) observed that the core home range and overall home range for free ranging cats did not change across the seasons which was in line with results from other research in other part of the world (Barratt 1997; Meek 2003; Morgan *et al*.2009; Thomas *et al.* 2014). Also, habitat selection shows significant difference in range sizes with cat preferring garden habitats more than natural and anthropogenic areas (Morgan et al. 2009, Woods et al. 2016). Hanmer et al. (2017) investigated how urbanization affects cats ranging behaviour in Reading. Cat home range area and the maximum distance reached from home varied increasingly from urban habitat through suburban and into peri-urban habitats, with a maximum range of 6.6ha and maximum distance of 278 meters.

1.5 Cats and their prey

Cats are successful generalist predators and opportunistic hunters, relying mostly on visual cues along with exceptional sound discernment capabilities in the hunt for her prey (Turner and Bateson 2000). In addition to their good hunting reflexes, cats can kill their prey swiftly and efficiently and are generally noted to prey on small mammals and birds (Floyd and Underhill-Day 2013). Evaluating the vulnerability of prey to predation by feral cats, it has been suggested that species up to 3 kg, but most frequently those below 200g (birds), and 230g (mammals) are mostly at risk and species that gather in seasons for feeding, breeding or hibernation and in small areas are also vulnerable to predation by cats (Dickman 1996).

Analysis of prey records from studies, in Canberra, Australia, highlighted 36 native mammals, 26 bird, 40 reptile, four insect, two fish and one amphibian species identified as prey of cats in Australia based on Dickman's (1996) categorization. Investigations from many studies taking advantage of cat habit of bringing back their prey home indicates that they also kill invertebrates, fish and herpetofauna (Barratt 1997; Woods et al. 2003; Baker et al. 2008; Hansen et al. 2010). In UK, at least 44 species of wild bird, 20 species of wild mammal, four species of reptile and three species of amphibian were recorded from such surveys (Woods et al. 2003). Records from prey brought home by cats in New Zealand and Australia, indicates that prey composition for the respective studies were mammals (86% and 65% respectively), birds (13% and 27%), and other vertebrates (8% and 1%) (Barratt 1997; Hansen 2010). In continental Australia analysis of faeces or gut contents highlights mean frequency of incidence of mammals, birds and reptiles in the feline diet to be 69.1%, 20.7% and 32.7% respectively (Fitzgerald and Turner 2000). A four-month observation period in a study in UK at Mawnam Smith, found that the prey population captured

(325 items) was composed of mammals (58.6%), birds (26.5%), reptiles (8.7%), and 6.2% for unidentifiable items (McDonald et al. 2015). Average estimation of proportions of different prey types (percentage of each prey type of the total as in table 2 below) from four different studies in the UK (Churcher 1987; Woods 2003; Baker 2008; Thomas et al. 2012; McDonald et al 2015) and one each from Scotland (Carss 1995), Australia (Barratt 1997) and New Zealand (Hansen 2010) indicates prey composition ranges from 61% - 85% for mammals, 9% - 27% for birds, 2% - 9% for herpetofauna and fish, and 3%-6% for unidentified items.

Table 2. The proportion of different prey types recorded in seven studies. The percentage of each prey type of the total for each study is given in parenthesis. (Modified from Baker et al. 2010; Thomas et al. 2012)

Source	Location	Mammals	Birds	herpetofauna/Fish	Inverts	Unknown
Churcher (1987)	UK	535 (49)	297 (27)			258 (4)
Carss (1995)	Scotland	195 (95)	11 (5)			
Barratt (1997)	Australia	1273 (65)	529 (27)	157 (8)		2 (0)
Woods (2003)	UK	9852 (69)	3391 (24)	1355 (9)	305 (2)	191 (1)
Baker(2008)	UK	269 (75)	86 (24)	3 (1)		
Hansen(2010)	New Zealand	253 (86)	37 (13)	3 (1)	3 (1)	
Thomas et al (2012)	UK	748 (65)	345 (30)	58 (5)		
McDonald et al (2015)	UK	190 (59)	86 (27)	28 (9)		20 (6)
Pirie et al. 2022	UK	311(69)	110(25)	20(3)	6(1)	33

Studies have also shown that prevalent among mammals prey are Rodentia (mice, voles, squirrels), Insectivora (shrews) and Lagomorpha (hares and rabbits), for the Aves prey species the Passeriformes (house sparrow, swallow, songbirds) being the most prevalent and for the Herpetofauna prey species, the most prevalent are Reptilia (skinks, lizards) (Woods 2003; Kays and DeWan 2004; Baker 2008; Thomas et al. 2012; Loss et al. 2013; McDonald et al. 2015; Kitts-Morgan et al. 2015; Palmas et al. 2017).

1.6 People's attitudes towards cats

An attitude is defined as "a learned predisposition to respond to an object in a consistently favourable or unfavourable way". Attitude and beliefs are linked with individual behaviours in the theory of reasoned action model (Fishbein and Ajzen 1975) and this approach advocates that the attitude of a person towards a behaviour is determined by his beliefs on the consequences of this behaviour, multiplied by their evaluation of these consequences. In the setting of human-animal relations, essentials of this theory have been espoused by Coleman et al. (2003), for example in observing that positive attitudes towards pigs were linked to their more caring handling and treatment (Toukhsati 2012).

The attitudes of people towards cats are diverse and can differ with culture at a variety of scales, cat ownership, conservation orientation, animal protectionists and public health practitioners, especially in contemporary settings where we have an abundance of research effort in the study of cats and predation. It is evident that while some persons and biodiversity conservationists may have concerns and reservations about the possible impacts of domestic cat predation on fauna, there exists also a commanding group of interested stakeholders that are more concerned with cat welfare (Loyd and Hernandez 2012). Those concerned with animal welfare and cat owners will usually rate cats as being a less severe problem than conservationists, environmentalists and indeed the public (Farnworth et al. 2014). It is important to understand opposing points of view, as this is vital in supporting convincing management measures and needed to assess the acceptability of any management measures among the special interest groups and the public (Decker et al. 2001; Bremer and Park, 2007). A study in Australia found that cat owners' opinions about the relevance of cat containment measures and positive attitude towards this approach were directly related to concerns about their cats' protection and likewise from the non-owners' perspective positive attitudes towards containment were associated with concerns about protection of fauna and humans from harm or cat nuisance (Toukhsati *et al.* 2012).

Haspel and Calhoon (1990) and Touhsati et al. (2007) directed their studies to address the attitudes and behaviours of 'semi-owners' of cats, where semi-owning is described as the deliberate provision of food, veterinary care and housing by an individual for a cat that is not owned by the individual (Haspel and Calhoon, 1990; Toukhsati et al. 2007). Semi-ownership was related to positive feelings towards cats and the belief that cats are independent. Using 424 residents from rural and non-rural Victoria in Australia to investigate their ownership position, practice and attitudes towards companion animals, results showed that 22% of the residents examined are involved in the semi-ownership of up to two cats through feeding activities. Such practices are also commonly found in the USA and Europe and seen to contribute to the high density of cats in urban areas (Haspel and Calhoon 1990, Natoli et al.1999). Levy et al. (2003) shows that 44% of cats in the USA are semi-owned. Similarly, Natoli et al. (1999) investigated three feral cat colonies in Rome and found that semi-owners provided accommodation, food and medical care for the cats at their own expense because of fear of the inability of the public veterinary services to properly care for the cats. Their behaviours can increase cat breeding success resulting in an overall unfavourable welfare outcome (Natoli *et al*. 1999).

Past investigations on community attitudes to cat management have been fruitful in recognising opportunities where the public are well-informed about the subject of neutering (Scriggins and Murray 1997, Grayson, Calver, and Styles 2002). Loyd and Hernandez (2012) in their Athens Clarke-County study concluded that information on public attitudes towards feral cats is paramount in guiding management of feral cats and should be scrutinized on a broader perspective and further highlighting that often public policy decisions are still largely influenced by advocacy groups with the machinery to be heard, and that this information is mostly inadequate (Sullivan 2009).

What is clear from reviewing the literature is that studies concerning attitudes towards cats and cat management are from a limited and unrepresentative group of countries (USA, Australia, and the UK). Given the global distribution in cats and their close association with people it is imperative that we gain a wider understanding of attitudes in regions where cultural differences may lead to very different perspectives of how these controversial issues should be managed.

1.7 Management strategies.

To date we have a limited number of research efforts that investigated the human dimension behind cat management issues (Ash and Adams 2003; Loyd and Miller 2010; Loyd and Hernandez 2012). In particular controversies surrounding feral cat management pivots around the positions of animal protectionist groups and cat owners which will usually rate cats as a less severe problem than pro-wildlife advocates (biodiversity conservationist, environmentalist) (Farnworth et al. 2014).

To help prevent cat predation from having a negative influence on biodiversity, it has been suggested that buffer zones should be formed with reasonable distances from areas containing species of conservation importance. Lilith et al. (2008) suggested buffer distances of 300-400 for Australia. Metsers et al. (2010) also suggested a 1.2km distance to combat the impact of cat predation in New Zealand. In the UK it has been suggested that habitats be managed to reduce rates of cat access or a buffer distance of 300-400m (Thomas et al. 2014), and Hanmer et al. (2017) suggested 335m between peri-urban housing and areas of conservation importance.

In the Oceanic Islands, eradication of feral cats have been repeatedly suggested as a management strategy (Mateo 2001; Silva and Mateo 2003; Rando 2005; Palmas et al. 2017). Collar wearing has also been suggested as a possible solution to reduce predation (Wood et al. 2003, Thomas et al 2012) and other devices such as sonic systems (Nelson et al. 2005) and bibs (Calver et al. 2007) have been recommended.

For now, there is little evidence that the broad swathe of public opinion recognises the damaging activities of cat predation, as there is scientific uncertainty pertaining to the extent to which cats threaten native wildlife populations (Lilith et al. 2006). On the other hand, cats are seen too to be at risk of predation by native carnivores, threats from vehicles, other domestic pets (dogs) and possible infection by disease (Crooks & Soule 1999; Grubbs & Krausman 2009; Bevins et al. 2012). Public awareness campaigns therefore have been suggested as a means of informing people and stepping up the awareness of problems occasioned by the release of pet cats and uncontrolled ranging into adjacent natural habitats

(Medina and Nogales 2009). Overall, issues around cat management presents quite a challenge and achieving a desirable result requires considerable engagement of the hearts and minds of stakeholders.

1.8 Aims and key objectives of this research

The aim of this study is to fill a much-needed gap in our knowledge of cat abundance, cat roaming and predatory behaviour, and people's attitudes towards them in an area representing a largely unstudied continent. By studying these questions within the megacity of Lagos, Nigeria, I hope to gain insights into possible effects of domestic cats in a representative region of central and West Africa. Nigeria is the most populated nation in West Africa and one of the largest economies in Africa with Lagos being among the top ten fastest-growing cities of the world. This study will focus on the following specific objectives.

1. To investigate empirically the attitude of Nigerians towards cats and the significant conservation question of cat predation and predation management using a series of questionnaire surveys.
2. To estimate the density of cats in the city of Lagos and hence estimate the local population sizes of cats in Nigeria using both questionnaires and line transect methods.
3. To monitor changes in the seasonal and daily ranging areas of owned domestic cats in Lekki, Lagos Nigeria using GPS and GIS techniques.
4. To monitor the prey returned by the cats in these areas and to quantify the most affected taxa and the numbers of prey killed by cats in Lekki-Lagos and around Lekki conservation centre.
5. To compare and contrast the attitudes of people who are either UK or Nigerian nationals and have been resident in their home countries since birth, with UK or Nigerian nationals who have moved to Nigeria or UK as adults respectively. In doing so we wish to understand both the effects of local culture, and the effects of exposure to different cultures, in attitudes to an animal of conservation concern.

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Chapter 2.

Attitudes towards cats and possible management options in Lagos, Nigeria.

2.1 Abstract

Cats (*Felis Catus*) are now one of the world's most common pets with popularity for companionship vastly increasing in many countries. Feral cats and free-roaming domestic cats are recognised as one of the world's major threats to biodiversity but our understanding of public awareness of these issues is limited to countries such as the UK, USA, and Australia. There is no information on whether the views reflected in these countries are local, or more widespread globally. In this study we examined how people in Nigeria view pet and feral cats, whether they see predation as an issue, and whether they would support mitigating actions. Using questionnaires, we recorded the responses of 664 respondents across Nigerian nationals largely living in Lagos. Lagos is the financial headquarters of sub-Saharan Africa and is one of the largest and fastest growing megacities in the world. An ordinal logistic regression using the Cumulative Link Model (CLM) in the R statistical Software was used to investigate associations between the location, age, gender, employment, high qualification, and cat ownership and the various attitudinal questions and management decision options about free roaming and feral cats. Results indicate that Nigerians have a positive view of pet cats with 73% agreeing or strongly agreeing that cats were harmless and that the risk of contracting a disease from a cat was considered low (71%). Although participants expressed concern about wildlife predation with 97% responding that free roaming cats harm wildlife ($P < 0.001$), this was influenced by academic qualifications ($P = 0.032$) and home type ($P = 0.01$). Illustrating the complexity of attitudes of Nigerians, a high proportion (81%) of respondents believe that cats are associated with witchcraft and a majority (57%) agree that it is acceptable to eat cats. On management suggestions, a high proportion of respondents agreed daytime and night-time curfews should be implemented, cats should be registered with the local government council, Trap Neuter Return and only 20.6% agreed with euthanizing feral cats. Though cat wearing collars or being neutered is not generally practised by cat owners in Nigeria, the majority of respondents are favourable disposed to them as a preferable line of action in managing cats. Study findings are expected to have great relevance for active management of threats from cats to species of conservation concern especially around the Lekki conservation centre, Lagos, Nigeria. Study reveals a strong need for public awareness about the threats of cats to species of conservation concern, and how management may be used to mitigate these effects.

2.1 Introduction

Felis silvestris lybica (the African wild cat) is considered the most likely ancestor of modern-day cats (Sepell 1988; Driscol 2007). A skeleton of an African wildcat was found beside a human skeleton in a Pre-Pottery Neolithic B settlement grave site that dates to about 9500 years ago and is the earliest known evidence to date for a close connection between humans and cats, indicating the likelihood of cats being tamed or domesticated (Vigne et al 2004), with full-scale domestication beginning some 3500 years ago (Morris

1996) with an early domestication starting point at the agricultural villages in the Near East (Driscoll et al 2007; Denny and Dickman, 2010).

The expansion of the Roman Empire into Europe is associated with the introduction and spread of cats into Europe (Driscoll et al. 2009) which would later introduce cats into the larger part of the world through her colonial activities (Dickman 1996; Coleman et al. 1997; Morling 2014). The entry of the domestic cat to present day Nigeria may thus have been from the British though the Portuguese were the first Europeans to set foot on present day Nigeria in the early 15th century in the wake of Atlantic Slave trade and then followed by the British who replaced the Portuguese as the leading merchants and whose forces occupied Lagos in 1851 (Unini 2020) and their colonial activities extended until Nigerian independence in 1960 (Meredith 2005).

Cat population growth has been a key factor in their spread. Studies shows that a female cat could give birth to as much as three litters per year and up to four kittens per litter with the strength to raise about twelve offspring successfully each year (Adamec 1976; Root et al. 1995). Also, the proclivity for cats to allow for territory sharing in shifts with neighbouring cats taking turns have been highlighted (Baker et al. 2010) and this adaptation of territorial use further accommodates increasing densities. Estimates of global cat populations have seen a jump of more than 300% in less than a decade between 2002 and 2009 (Clutton-Brock, 2002; Driscoll et al. 2009) and with projected high rates of urban expansion and population (United Nations 2014) population density of cat is expected to increase accordingly and in some urban areas 200–2000 cats are found per km^2 (Liberg et al. 2000; Sims et al. 2008; Baker et al. 2010; Thomas et al. 2012). Attendant issues of cat predation will increase, particularly in residential developments near areas of biodiversity value (Goddard et al. 2009; Pirie et al 2022).

Cats are considered the most prevalent mammalian predator and outnumber all others in combination in most climes with high human population densities (Harris *et al*. 1995; Battersby 2005, Blancher 2013; Loss *et al.* 2013; Hanmer *et al*. 2017). Several studies have revealed the possible ecological impacts of cats on native fauna through predation (Towns et al. 1990; Lowe et al. 2000; Baker et al. 2005; Medina et al. 2011; Loss et al. 2013; Doherty et al. 2016; Pirie et al. 2022). Estimates of wildlife mortality credited to feral and domestic cats is projected in very high ranges, with predation on bird populations perhaps being considered more contentious and controversial (Peterson et al. 2012). While the direct predatory impact of cats is already well understood in some regions, it is argued that risk-aversion effects on wildlife and other indirect impacts of cats such as disease transmission and competition with indigenous predators may have greater consequences on prey populations than direct predation (Tidemann 1994; Dickman 1996; Preisser et al. 2005; McCarthy 2005; George 2010). However, while there are growing concerns about cat predation activities and their seemingly destructive impacts, there remains a challenge to finding evidence of effects in some regions and habitats (Crooks and Soule 1999; Lilith et al. 2010; Thomas et al. 2012) and specifically explicit confirmation of a negative effect on prey populations in urban areas as uncertainty remains regarding the degree to which cats threaten wildlife populations in these areas (Lilith et al. 2006).

People's responses to the predatory behaviour of cats seems to becoming increasingly negative (Chaseling 2001; Marra and Santella 2016 provide a popular science overview), although this can provoke strong arguments and opposing perceptions. While these concerns have brought issues of cat management to the fore, with a strong call for proactive cat management procedures to be in place and several advocated for implementation (Lilith *et al*. 2006; Calver *et al*. 2011), to help prevent cat predation from having a negative influence on biodiversity. Suggested options for cat management includes: (1) Ban on cat ownership, were no one residing in a town or city is permitted to own a cat and among people residing in/near ecologically sensitive areas (Lilith *et al*. 2008; Metsers et al. 2010; Thomas et al. 2012). 2) Wearing of collar bells or any other anti-predation gadgets (Ruxton et al. 2002; Calver et al. 2007; Gordon et al. 2010). 3) Curfews or temporary confinement. 4) Registration of cats with the local government council. 5) Neutering of cats. 6) Protection of feral cats and managed as wildlife. 7) Euthanizing of feral cats and 8) Trap Neuter Return (where feral cats are captured, neutered, and released back into the wild). Issues around cat management presents quite a challenge and achieving desirable results requires considerable engagement of all stakeholders (Farnworth et al 2014).

Deep rooted societal beliefs and culture seems to influence people's attitudes towards cats (Metzer 2009), no differently to the development of individuals' attitudes towards any object or behaviour, which can be formed from their state of mind, and be either positive, neutral or negative concerning a particular place, issue, entity, thing, event, or behaviour and which are belief rooted about that thing (Gramza et al. 2015). Attitudes are often idiosyncratic or distinctive and hence situations abound where some attitudes are held even in the presence of available evidence to the contrary (Fraser 2001). Cultural beliefs and myths have been associated with the domestic cats over time and in different places (Metzer 2009). In Nigeria, the major tribes Yoruba, Hausa, Ibo, and other tribes such as the Ibibio and Kanuri peoples believe that cats are used by witches and wizards to cause havoc and other evils in the society, because they prefer to use cats as their spiritual transformation medium using their mystic powers (Bukar-Kolo et al. 2018). These cultural beliefs are passed down from generation to generation. The antipathy towards cats is very regionally distinct, as in Muslim areas of Nigeria most houses may have cats as it is believed that affection for cats is part of faith (Daily Sabah 2017).

In depth appreciation of public attitudes towards cats is required to better understand the complex issues associated with cat management (Loyd and Hernandez 2012). Russell (2014) echoed the view of Redpath et al. (2012) in that most conservation conflict in wildlife management is basically that of a human-human issue and Liu et al. (2011) suggest that people's perception of risk and uncertainty plays key roles in decision-making frameworks for wildlife management. It is certain that while some persons and biodiversity conservationists may have concerns and reservations about possible impacts of domestic cat predation on fauna, there exists also a group of interested stakeholders that are also concerned about cat welfare (Loyd and Hernandez 2012). Attempts to implement a management decision that is purely the product of either the conservationist or non-conservationist point of view without considering overarching public attitudes, may generate social conflict that will render the management initiative in the unsuccessful (Fitzgerald 2009; Russell 2014). Lloyd and Hernandez (2012) flagged that the 'contentious issue of feral cat management requires a greater understanding of public attitudes towards cats and preferences'; the need therefore to understand in depth the range of opinions concerning cat management is evident.

The human dimensions behind the question of cat management have been studied by very small number of geographically limited research efforts (Ash and Adams 2003; Lord 2008; Loyd and Miller 2010; Lloyd and Hernandez 2012; Hall et al. 2016). There is a lack of information presently on public and other group's attitudes towards cats and their management in Africa. Nigeria, an African country on the Gulf of Guinea, is the most populous country in Africa with population of over 206 million and is one of the largest economies in Africa (Worldbank, 2020). Vegetation cuts across the saltwater swamp forest to the dense rainforest belt that reaches into the savanna and then the Sahara Desert. Key natural landmarks and wildlife reserves in Nigeria includes the Zuma rock around the country capital Abuja, the Jos Plateau and Obudu Cattle range, Yankari Game Reserves and Cross River National Park which provides for habitats for rare primates including drills, gorillas, and Mona monkeys.

The primary intent of this research is to investigate people's attitudes towards cats and their management in Nigeria. Towards this end, factors such as experience, knowledge of cats and attitudes towards cats will be explored in depth to aid policy makers in their understanding of the underlying controversies to provide robust management initiatives. This study is the first in Africa to address these issues and therefore focuses on examining people socioeconomic status, experiences, knowledge of cats, and attitudes towards cats and cat management in Nigeria.

2.2 Methods

2.2.1 Study Area

This survey was conducted in Lagos, Nigeria and within the general location defined by the coordinates: 6°27′ 14.65″ N, 3°23′ 40.81″ E during 2019 - 2020. Lagos is the most densely populated city in Nigeria with an area of 1,171 km² and with an estimated population of 21m people (Rosenthal 2012). The city of Lagos is located at the Southwestern Geopolitical zone of Nigeria, a melting pot of Nigeria's diverse ethnicities. Lagos is bounded in south by the Atlantic Ocean and has made it one of the great port cities in sub–Saharan Africa. Clusters of rain forest and farmland abound in the Lekki Peninsular axis which also contains the Lekki Conservation Centre.

2.2.2 Questionnaire

We examined people's attitudes in Nigeria to help gain an understanding of how attitudes to the significant conservation question of cat predation management options are appreciated across the Nigerian populace. In designing the survey questionnaire, I leveraged questions used in previous studies (Lloyd and Hernandez 2012; Thomas et al. 2012). The questionnaire survey was divided into five different sections: (1) Demographic information (10 questions); (2) Cat ownership status and care (9 questions), for participants who did not keep cats reasons for not keeping cats were asked and given options and opportunity to state reasons if different from what is listed (6 questions); (3) Participant interest in wildlife and backyard characteristics (6 questions); (4) Participant attitudes towards cats in regards to general thoughts on feral and pet cats, and risk of disease and towards wildlife which was accessed on a five-point Likert scale (Likert 1932; 16 questions) and (5) Participant preferences for management options for feral and owned cats also on a five-point Likert scale, in response to a preliminary declaration: "If it is found that cats are affecting wildlife, and management decisions have to be made to reduce this, please indicate whether you strongly agree, agree, neutral, disagree, strongly disagree to these management options" (12 questions; Appendix 3). The questionnaire was pre-tested by 30 volunteers for understanding of phrasing and content and it took each person approximately 10-15 minutes to complete the questionnaire. The project was subject to ethical review according to the procedures specified by the University of Reading Ethics committee and has been given favourable ethical opinion for conduct. The study was approved by the University of Reading School of Biological Sciences ethical review committee (reference SBS16-17 18).

Only participants who were above 18 years of age were qualified to enter in the survey to comply with ethics.

2.2.3 Data collection

Data collection was carried out through a door-to-door sampling using the Crowdsignal application (Crowdsignal 2008) with questionnaires saved on iPads. Also, an online survey was completed using the link: https://pawrg.polldaddy.com/s/global-cattitudes-survey from the Crowdsignal application, where we asked people to pass on to friends, colleagues and relatives and other respondents in Nigeria who were contacted via email and social media. Printed hard copies were left with some household members who were not ready to participate immediately and in some offices which were collected a few days later and data inputted into Crowdsignal page via link.

2.2.4 Data analysis

Not all questions in Crowdsignal were set as being compulsory and hence not all respondents answered all questions; as such sample sizes vary. An ordinal logistic regression using the Cumulative Link Model (CLM) in the R statistical Software (R Core Team 2018, version 3.5.1, package: ordinal) was used to investigate associations between the location, age, gender, employment, high qualification, and cat ownership (independent variables) and the various attitudinal questions and management decision options (dependent variables) about free roaming and feral cats (Coughlin & van Heezik, 2014).

A backwards stepwise technique was used to refine the model, by sequentially removing non-significant predictors and refitting to identify which predictors were important (Crawley 2010). Models results with lowest AIC values were considered as best models even though there might be one or two independent variables with p value greater than 0.05 when it was found that on the removal of those variable the AIC value rather increases. Only outcomes that were statistically significant were considered for use in the interpretation.

2.3 Results

Data were collected from a total of 664 respondents across Nigerian nationals living in Lagos and some outside of Lagos. Out of the 664 respondents that participated in the survey, the most frequent age bracket was 26-35 (33%; Figure 2A), there was almost an equal participation of the female and male respondents (Figure 2B). Respondents that owned cats constituted 19% of total respondents and pest control ranked the highest reason for keeping cats (Figure 2C). Cat ownership status and percentage distribution of respondent reasons for owning cats and other related items are shown in Table 2.2 (Appendix-1).

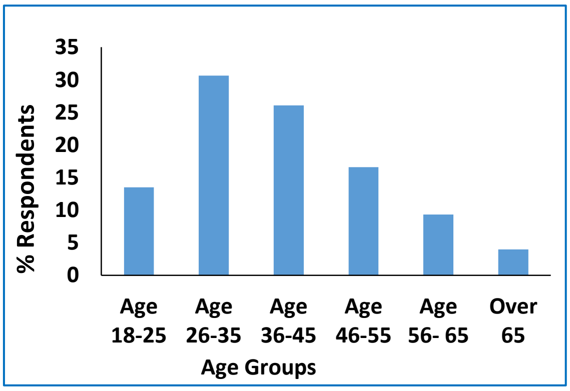

Figure 2A: Age participation %

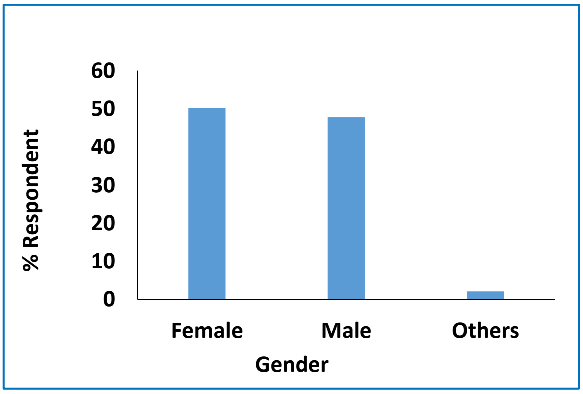

Figure 2B: Gender participation %

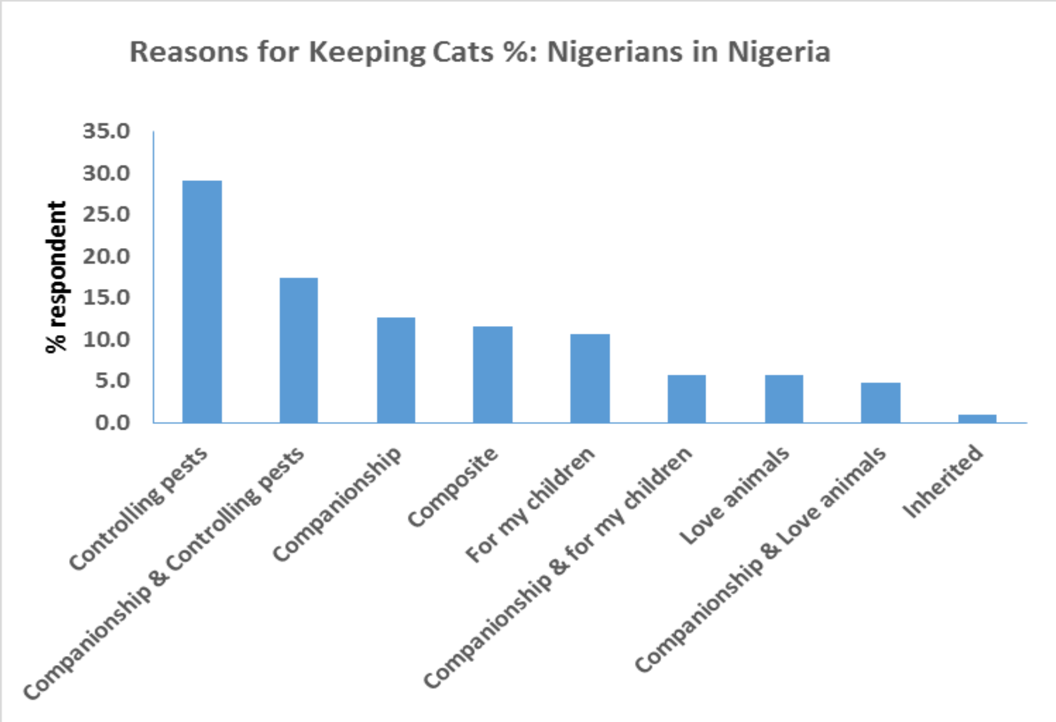

Figure 2C: Reasons for keeping cats.

2.3.1 Attitudes and beliefs towards domestic pet cats

Results indicate that Nigerians have a positive view of pet cats with 73% agreeing or strongly agreeing that cats were harmless and that the risk of contracting a disease from a cat was considered low (71%). One hundred percent of Nigerians also accepted that pet cats live healthy and happy lives. Responses to the attitudinal questions towards cats are given for all Nigerian participants in Table 2.6 (Appendix-1) and the responses of cat owners only are given in Table 2.7 (Appendix-1). Nigerian people are significantly more likely to agree that cats are harmless than harmful ($P < 0.001$). This belief was especially seen amongst the older people ($P = 0.008$) with higher educational qualifications ($P = 0.05$) and those not owning cats ($P = 0.008$). Although participants expressed concern about wildlife predation with 97% responding that free roaming cats harm wildlife ($P < 0.001$), this was influenced by academic qualifications ($P = 0.032$) and home type ($P = 0.01$) (Table 2.9a; Appendix-1), as people with educational qualifications were significantly more likely to agree or strongly agree that free roaming cats harm wildlife. People who lived in caravans or temporary accommodation were seen to be less likely to agree to this statement.

2.3.2 Attitudes and beliefs towards feral cats

Only 67% of respondents accepted that feral cats live healthy and happy lives, and in addition feral cats were considered a nuisance by 67% of respondents and 62% worried about the problems that feral cats might cause for their pets, even though more than half of the respondents (63%) also felt that feral cats have the right to live in their neighbourhood and 66% felt that feral cats should be offered food and shelter. Concerns that feral cats were considered to constitute a nuisance was dependent on the demographic variables of age (P = 0.004), occupation (P = 0.001), academic qualifications (P < 0.001) and cat ownership (P < 0.007); younger Nigerians with low educational qualifications and who do not own cats were more likely to strongly agree that feral cats are a nuisance. The belief that feral cats have the right to live in their neighbourhood was found to be significantly influenced by residential location (P < 0.001), age (P < 0.001), academic qualification (P < 0.001) and cat ownership (P < 0.001), (Table 2.9a; Appendix-1). Younger respondents with low educational qualifications, who do not own cats were more likely to strongly agree. Eighty one percent of respondents felt that cats are associated with witchcraft while 57% agree that it is acceptable to eat cats (Table 2.6 Appendix-1).

2.3.3 Cat management options

The option of feral cats being protected and managed as wildlife had 84.8% in agreement (Table 2.8; Appendix-1). Only 5% of respondents did not agree that more effective management of cats was needed and this was found to be significantly influenced by residential location (P < 0.001), occupation (P < 0.001) and cat ownership status (P = 0.001; Table 2.9b Appendix -1). Of the respondents 77.2 % and 78.1% agreed daytime and night-time curfews should be implemented, 91.0% agreed cats should be registered with the local government council, 88.1% agreed with Trap Neuter Return (where feral cats are captured, neutered, and released back into the wild) and only 20.6% agreed with euthanizing feral cats. The low acceptability of euthanizing feral cats was found to be significantly influenced by the demographic variables of age (P < 0.005), gender (P < 0.004), employment (P < 0.01), occupation (P < 0.001) and qualifications (P < 0.005; Table 2.9b; Appendix -1). Further results of the ordinal regressions from the cumulative link models are given in Appendix -1 (Table 2.9b).

Results also indicated that 85.5% of respondents accept the management option that restricts people residing in ecologically sensitive areas from owning cats and 90.7% agree with cats wearing bells or other anti-predation devices. People residing in ecologically sensitive areas should not be permitted to own cats was significantly influenced by location (P < 0.001), home type (P < 0.011) and cat ownership (P < 0.001) only, while the suggestion that cats should wear bells or any other anti-predation gadgets was found to be influenced by location (P < 0.001), occupation (P = 0.001), qualification (P < 0.001) and cat ownership status (P < 0.001) (Table 5.9b; Appendix-1).

2.4 Discussion

Cats are considered a significant threat to wildlife, but our understanding of public awareness of these issues is limited to countries such as the UK, USA, and Australia. There is no information on whether the views reflected in these countries are local, or more widespread globally. In this study we examined how people in Nigeria view pet and feral cats, whether they see predation as an issue, and whether they would support mitigating actions. Using questionnaires, we recorded the responses of 664 respondents across Nigerian nationals largely living in Lagos. Lagos is the financial headquarters of sub-Saharan Africa and is one of the largest and fastest growing cities in the world (investment monitor, 2021). The findings reveal that cat ownership status is at 19% of the surveyed population, and pest control and companionship were the primary reasons for owning cats. A high proportion of respondents have positive views on cats, considering them to be harmless and that there is a low possibility of their transmitting diseases. Percentage agreement that pet cats and feral cats live healthy and happy lives stood at 100% and 67% respectively. More than 77% agreed with non-lethal management options to reduce rates of cat predation, particularly near areas of conservation value. Illustrating the complexity of attitudes, a high proportion (81%) of respondents believe that cats are associated with witchcraft and a majority (57%) agree that it is acceptable to eat cats.

2.4.1 People's attitude towards pet and feral cats

This study's outcome indicates that the majority of Nigerian respondents agreed or strongly agreed that cats are harmless and the risk of contracting a disease from a cat was low. Older respondents with higher educational levels and non-cat owners were more likely to be in this group. A slight majority considered feral cats to be a nuisance and also worried about the problems that feral cats might cause for their pets. Fewer respondents agreed that feral cats live healthy and happy lives and felt that feral cats have the right to live in their neighbourhood and should be offered food and shelter. These scenarios indicates that the Nigerian public perceptions of domestic and feral cats are mixed, comparing and aligning with information from other studies (USA: Ash and Adams 2003; Loyd and Miller 2010; Loyd and Hernandez 2012; Gramza et al. 2015; UK: Thomas et al. 2012; New Zealand: Walker et al. 2017), where pet cats are viewed highly favourably, in contrast to perceptions of feral cats, which are more often considered pests.

Gender is a deep-rooted variable often influencing attitudes towards animals (Kellert and Berry 1987). In general, studies find that males are seen to maintain a more practical view of animals with greater concern for species and habitat preservation (Herzog et al. 1991; Eldridge and Gluck 1996; Serpell 2004), while women are seen to put greater value on compassion and protection of individual animals (Miller & Jones 2006; Walker et al. 2014). In corroboration, this study found that the at par proportion of male and female respondents might have some impression on some of the not too high support level on the attitude respond on cats predation and problem questions (I feel that feral cats have the right to live in my neighbourhood; I worry about problems feral cats might cause for my pets; I feel feral cats are a nuisance) and these also corresponds to where the output of the regression models were non-significant for the gender demographic variable.

This study shows that spiritual reasons were a key reason for not owning cats. It is strongly believed that cats can be spiritually possessed and can be used for negative reasons in witchcraft (Bukar-Kolo et al. 2018) and the high proportion 81% of respondents believing that cats are associated with witchcraft is the highest in studies of these nature. In the argument in support of not owning cats, the reason that cats carry diseases ranked second and possible highlighting the strong belief in Africa that cat's hair when mistakenly swallowed brings deadly diseases, which is closely associated with cats being the main carriers of *Bartonella henselae* infection (cat-scratch fever) through their fur (Greenblatt et al. 2013). Apart from other health issues associated with cats, results show that cats being expensive to keep came last in ranking as a reason for not keeping cats and possibly highlighting the fact that pet cats are mostly free roaming and veterinary care is rare.

Cat eating is endemic in Nigeria and results showed that it is generally considered acceptable to eat cat meat. Interactions during the survey with cat owners and non-owners alike confirmed that cat meat is a sought after meat because of the sweetness, although it is believed that it is bad luck for the cat to behold the killer. Respondents also confirm the high value rating of cat body parts in traditional medicine in Africa, which additionally has contributed to the high mortality rate of cats and the possible attendant limiting effect on cat population growth cannot be overemphasized.

2.4.2 Perceptions of negative cats' impacts on faunas and people

Many respondents (97%) agreed that free roaming cats harm wildlife and expressed serious concerns about wildlife predation, and this was more likely to be supported by those with higher education levels and living in permanent homes (a meaningful number of people living in Lagos live in impermanent homes, such as shanties and caravans). Nigerians perceptions of cats is somewhat biased against feral cats as most respondents do not believe that the domestic cats do much harm to wildlife and majority feels that free roaming and feral cats are more likely to harm wildlife, although studies have shown that the hunting behaviour of domestic cats, though being catered for by humans, is hardly subdued (Adamec 1976; Biben 1979; Turner and Meister 1988; Turner and Bateson 2000). Lower levels of concern regarding domestic cat predation have been reported in other studies (Lilith et al. 2006; Thomas et al. 2012; Walker et al. 2017) perhaps because most cat owners only get to see a small aspect of their cat predation, and do not appreciate the prey eaten at site or not returned home, nor the possible combined effect of the domestic cat population as a whole. Studies have shown that relying solely on prey returned alone grossly underestimates predation rates of urban cats (Krauze-Gryz et al. 2012; Morling 2014).

A small proportion of cat owners felt that pet cats are harmless to wildlife compared to the greater majority of respondents (73%), and contrary to the position that cat owners were more likely to disagree that cats were doing harm to wildlife (Loyd and Hernandez 2015). This also reveals that cat owners in Nigeria recognise the possible predation effects of cat on wildlife but are less aware of the resulting consequences and management options that could mitigate this threat. This highlights the need for public awareness campaigns and knowledge about cat predation and management options as a means of informing people and stepping up the awareness on problems caused by the release of pet cats and uncontrolled ranging into the natural habitat as also suggested by Medina and Nogales (2009). Cat predation is a contemporary conservation challenge (Schultz 2011) and a good understanding of solutions needs human behavioural changes (Gramza et al. 2015); to achieve this we need to understand the starting point with regards people's attitudes, feelings, and beliefs (Fishbein and Ajzen 2010).

2.4.3 Management decision options

This study suggests that more effective management of cats is needed which implies that it is appropriate and timely for the consideration of methods for managing cat populations and possible predation in Nigeria as other studies have suggested in other regions (Baker at al. 2008; Thomas et al. 2012). Positive public attitudes in this direction as this study has shown is required to better handle the contemporary and complex issues of cat management as noted in other studies (Loyd & Hernandez 2012; Redpath et al. 2012; Russell 2014). Our survey demonstrated strong public agreement from respondents with the suggestion that cats should wear collar bells or any other anti-predation gadgets. Other studies (Nelson et al. 2005; Gordon et al. 2010; Thomas et al. 2012) have highlighted the same suggestions, but these are not a panacea for all scenarios (Van-Heezik et al. 2010). The management option that cats should be registered enjoyed an overwhelming acceptability with respondents and this is in line with the international levels of support recorded in other studies at other geographic locations (Lilith et al. 2006), although among the cat owners this was not as overwhelming as only a slight majority responded positively, suggesting that non-cat owners were more likely to support active approaches to cat management.

While the management suggestions that cats wearing collars or being neutered is not generally practised by cat owners in Nigeria, the majority of respondents are favourable disposed to these management options as a preferable line of action in managing cats. The rate of support for neutering in Nigeria is within ranges of studies in other countries, with support at 86% in Singapore (Gunaseelan et al. 2013), 88–93% in Australia (Perry 1999, Lilith et al. 2006), 93% in New Zealand studies (New Zealand 2016; Hall et al. 2016), and lower values of 58% in New Zealand (Walker et al. 2017), 60.9% in Reading, UK (Thomas et al. 2012). Respondents show relatively good support to suggestion that people in eco-sensitive areas should not own cats which is in line with what have been reported in other studies abroad (Lilith et al. 2006; Gordon et al. 2010; Walker et al. 2017). Also, respondents showed low levels of support (<20 %) for curfews for cats and even less than 10% for general confinements are also in line with findings from other international studies in which cat confinement has been found to be equally an unpopular option (Lilith et al. 2006; Hall et al. 2016; Walker et al. 2017). On the management option that feral cats are trapped neutered and released back into the wild, study shows that in all the cases the respondents lean towards being neutral about this management option.

2.5 Conclusion

The importance of understanding of the prevalence and diversity of different attitudes towards cats and their control cannot be over emphasized. This study focuses effort on Nigerian people's attitudes towards cats and their orientation towards management options. This study included residents in areas within a reasonable distance of the Lekki Conservation centre, a large biodiversity conservation park in the centre of the Lekki stretch in Lagos, Nigeria. Here predation potential is heightened by a greater likelihood of cat–wildlife interactions, and so study findings are expected to have great relevance for active management of threats from cats to species of conservation concern.

This work finds an interesting duality in attitudes towards cats. Pet cats are considered with affection, and feral cats to a lesser extent, but we find effects of culture and deep-rooted myths, with negative views of cats as being associated with witches and wizards, and the issue of high cat mortality due to the acceptability of eating cat meat. This study reveals a strong need for public awareness about the threats of cats to species of conservation concern, and how management may be used to mitigate these effects. Nigerians strongly support the following options for managing the populations and predation of domestic owned cats and feral cats: (1) People in eco-sensitive areas should not own cats, (2) All cat to wear collar bells/ anti-predation gadgets, (3) Cats be registered with the local council, (4) Cats should be neutered, (5) Feral cats be protected and managed as wildlife.

At the same time, Nigeria is a very large, highly populated and ethnically diverse country. While this work is the first to gain insights into a key issue of urban conservation concern, it is likely that there may be considerable differences in attitudes to uncover across the country in future work.

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2.6 Appendixes

Tables

Table 2.2: Cat ownership status and percentage distribution of respondent's reasons for owning cats (NN).

Cat ownership status related items		Participation	% Respondent
Cat ownership status			
	Non-Cat Owner	561	84.49
	Yes, Cat Owner	103	15.51
Reasons for keeping cat			
	Companionship	13	12.62
	Companionship, Controlling pests	18	17.48
	Companionship, For my children	6	5.83
	Companionship, Love animals	5	4.85
	Controlling pests	30	29.13
	For my children	11	10.68
	Inherited	1	0.97
	Love animals	6	5.83
	Composite	12	11.65
Reasons for not keeping cats			
	Cat kill small animals	43	7.66

	Cats are expensive to keep	11	1.96
	Cats carry diseases	127	22.64
	Inhumane to keep cats	16	2.85
	No space to keep cats	60	10.7
	Spiritual reasons/can easily be possessed	245	43.67
	Other reasons	59	10.52
Cat neutered or not neutered			
	No	82	79.61
	Yes	10	6.79
	Yes, females only	3	2.91
	Yes, males only	3	2.91
	Yes, some of them	4	3.88
Cat wear collar or not			
	No	98	95.1
	Yes, with anti-predation collar or bell	1	1
	Yes, standard without a bell	5	4.9
Cat brings back wildlife			
	NO	10	9.71
	YES	93	90.29

Table 2.3. Percentage distribution of respondent's reasons for not owning cats (all residential locations)

Reasons for not owning cats.					
Nigerians' resident in Nigeria		%	**Nigerians' residents in UK**		%
Cats kill small animals	43	7.66	Cats kill small animals	4	1.7
Cats are expensive to keep	11	1.96	Cats are expensive to keep	24	10.3
Cats carry diseases	127	**22.64**	Cats carry diseases	16	6.8
Inhumane to keep cats	16	2.85	Inhumane to keep cats	30	12.8
No space to keep cats	60	10.70	No space to keep cats	67	**28.6**
Spiritual reasons/can easily be possessed	245	**43.67**	Spiritual reasons/can easily be possessed	36	15.4
Other reasons	59	10.52	Other reasons	57	24.4
UK residents in Nigeria		%	**UK residents in UK**		%
Cats kill small animals	4	1.7	Cats kill small animals	8	3.2
Cats are expensive to keep	24	10.3	Cats are expensive to keep	40	**15.9**
Cats carry diseases	16	6.8	Cats carry diseases	7	2.8
Inhumane to keep cats	30	12.8	Inhumane to keep cats	13	5.2
No space to keep cats	67	**28.6**	No space to keep cats	27	10.8

Spiritual reasons/can easily be possessed	36	15.4	Spiritual reasons/can easily be possessed	6	2.4
Other reasons	57	**24.4**	Other reasons	150	**59.8**

Table 2.6: Attitude and belief responds about cats for Nigerians in Nigeria.

Attitude /Opinions/Belief responds about cats for Nigerians in Nigeria (Reference case)							
	Strongly agree (%)	Agree (%)	Neutral (%)	Acceptability (%)	Disagree (%)	Strongly disagree (%)	Un-acceptability (%)
I feel that feral cats have the right to live in my neighbourhood	56	6	0	63	19	19	37
I worry about problems feral cats might cause for my pets	37	12	13	62	19	19	38
The risk of contracting a disease from a cat is low	29	26	16	71	3	26	29
Feral cats should be offered food and shelter	31	25	9	66	19	16	34
Feral cats live healthy & happy lives	31	22	10	63	16	22	37
Pet cats live healthy & happy lives	76	21	3	100	0	0	0
Cats control pests in my locality	85	12	0	97	3	0	3
Cats are harmless	48	21	3	73	3	24	27
Cats make good pets	88	9	0	97	3	0	3
I feel feral cats are a nuisance	45	18	3	67	15	18	33
Free-roaming cats harm wildlife	50	22	25	97	0	3	3
It is acceptable to eat cats	51	3	3	57	12	30	43

Cats are associated with witchcraft	58	7	16	81	13	6	19

Table 2.7: Cat owner's attitude and belief responds about cats for Nigerians in Nigeria.

Cat owners' attitude /feeling responds for Nigerian in Nigeria (Reference case)					
	Strongly agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly disagree (%)
I feel that feral cats have the right to live in my neighbourhood	57	6	0	19	18
I worry about problems feral cats might cause for my pets	36	12	13	19	19
The risk of contracting a disease from a cat is low	28	27	16	3	26
Feral cats should be offered food and shelter	30	27	9	18	15
Feral cats live healthy & happy lives	30	21	11	15	22
Pet cats live healthy & happy lives	75	21	4	0	0
I feel feral cats are a nuisance	44	19	3	17	17
Free-roaming cats harm wildlife	48	22	27	0	3
It is acceptable to eat cats	50	3	4	14	30
Pet cats should be kept indoors	45	13	6	19	17
Pet cats should wear a collar & bell	57	12	6	16	10
Pet cats should be licenced	56	13	15	7	9
Cats are associated with witchcraft	57	7	16	14	6
Cats control pests in my locality	46	43	0	11	0
Cats are harmless	13	36	5	5	41

Cats make good pets	52	35	0	12	0

Table 2.8: Management decisions responds about cats for Nigerians in Nigeria.

Management decisions responds for Nigerians in Nigeria (Reference case)								
	Strongly agree (%)	Agree (%)	Neutral (%)	No response (%)	Acceptability (%)	Disagree (%)	Strongly disagree (%)	Non acceptability (%)
No one residing in a town or city should be permitted to own a cat.	31.1	32.0	9.9	1.2	74.2	15.5	10.4	25.8
People residing in ecologically sensitive areas should not be permitted to own cats.	33.6	38.0	12.8	1.2	85.6	9.3	5.1	14.4
All cats should wear collar bells or any other anti-predation gadgets	22.5	50.0	16.2	2.0	90.7	5.7	3.6	9.3
Cats should not be permitted out during the day	17.4	31.8	25.2	2.7	77.2	14.1	8.7	22.8
Cats should not be permitted out at night	27.2	30.2	18.9	1.8	78.1	12.3	9.6	21.9
Cats should not be permitted to roam outside their owner’s garden	19.1	34.7	29.9	2.3	85.9	6.2	8.0	14.1
Cats should be registered with the local government council	36.0	40.4	12.2	2.4	91.0	5.7	3.3	9.0
Cats should be neutered	35.3	29.1	15.3	2.7	82.4	11.7	5.9	17.6

More effective management of cats is needed	35.4	49.1	9.2	1.5	95.2	2.4	2.4	4.8
Feral cats should be protected and managed as wildlife	24.2	40.5	17.9	2.3	84.8	7.5	7.7	15.2
Euthanizing feral cats is not acceptable	14.0	26.3	34.5	4.7	79.4	9.0	11.6	20.6
Trap Neuter Return (where feral cats are captured, neutered, and released back into the wild)	20.7	23.6	37.5	6.3	88.1	8.3	3.6	11.9

Table 2.9a: The Cumulative Link models (CLM) outputs for Attitude Questions in NN (reference case only)

Dependent variables (Attitudinal questions)	**Variables in the final model**	**DF**	**Coefficient/Estimate**	**SE**	**Z-values**	**P-values**
I feel that feral cats have the right to live in my neighbourhood	NN	1	-1.451	0.12	-12.73	<0.001
	Age	1	-0.125	0.04	-3.42	<0.001
	High qualification	1	-0.222	0.05	-4.61	<0.001
	Cat ownership	1	-0.534	0.13	-4.25	<0.001
Model1 clm(fer_live1 ~ factor(n_n1) + age + high_qul + factor(cat)) AIC = 4513.7						
The risk of contracting a disease from a feral cat is low	NN	1	-0.655	0.11	-6.07	<0.001
	Age	1	-0.096	0.04	-2.64	0.008
	Occupation	1	0.063	0.02	3.37	<0.001

	High qualification	1	-0.111	0.05	-2.25	0.024
	Cat ownership	1	-0.588	0.13	-4.64	<0.001
Model1 clm(fer_disease1 ~ factor(n_n1) + age + occ + high_qul + factor(cat)) AIC = 4533.5						
I feel feral cats are a nuisance	NN	1	-0.082	0.11	-0.78	0.438
	Age	1	0.104	0.04	2.87	0.004
	Occupation	1	-0.059	0.02	-3.24	0.001
	High qualification	1	0.183	0.05	3.77	<0.001
	Cat ownership	1	0.331	0.12	2.69	0.007
Model1 clm (fer_nuis1 ~ factor(n_n1) + age + occ + high_qul + factor(cat)) AIC = 4621.7						
Free-roaming cats harm wildlife	NN	1	-0.909	0.11	-8.36	<0.001
	Age	1	0.069	0.04	1.86	0.063.
	Occupation	1	-0.034	0.02	-1.83	0.067
	High qualification	1	0.106	0.05	2.13	0.032
	Home type	1	-0.062	0.02	-2.57	0.010
	Cat ownership	1	0.205	0.13	1.59	0.111
Model1 clm(cats_wildlife1 ~ factor(n_n1) + age + occ + high_qul + home_type + factor(cat)) AIC = 4003.9						
	NN	1	-1.375	0.10	-13.28	<0.001

It is acceptable to eat cats	Gender	1	0.340	0.09	3.83	<0.001
	employment	1	0.087	0.03	2.71	0.007
	Occupation	1	-0.085	0.02	-4.24	<0.001
	Cat ownership	1	0.518	0.14	3.66	<0.001
Model formula: Model1 <- clm(eat_cat1 ~ factor(n_n1) + gender + emp + occ + factor(cat)) AIC = 4181.6						
Cats are associated with witchcraft	NN	1	-2.100	0.11	-18.80	<0.001
	Age	1	0.069	0.04	1.79	0.073
	Gender	1	0.204	0.09	2.28	0.023
	Employment	1	0.073	0.03	2.23	0.026
	Occupation	1	-0.067	0.02	-3.33	<0.001
	Home type	1	0.055	0.02	2.21	0.027
	Cat ownership	1	0.547	0.14	3.94	<0.001
Model1 <- clm(cat_witch1 ~ factor(n_n1) + age + gender + emp + occ + home_type + factor(cat)) AIC = 4091.3						
Cat control pests in my locality	NN	1	-3.009	0.14	-21.07	<0.001
	Age	1	0.123	0.04	2.98	0.003
	Gender	1	0.256	0.10	2.57	0.010
	High qualification	1	0.168	0.06	2.95	0.003
	Home type	1	-0.056	0.03	-1.83	0.065

	Cat ownership	1	0.036	0.15	0.24	0.805
model1 <- clm (cat_pests1 ~ factor(n_n1) + age + gender + high_qul + home_type + factor(cat)) AIC = 3050.6						
Cats are harmless	NN	1	-1.420	0.11	-12.54	<0.001
	Age	1	-0.090	0.04	-2.55	0.008
	Employment	1	0.045	0.03	1.47	0.141
	Occupation	1	0.057	0.02	3.06	0.002
	High qualification	1	-0.092	0.05	1.90	0.050
	Cat ownership	1	-0.330	0.12	-2.64	0.008
Model1 <- clm (cat_harm1 ~ factor(n_n1) + age + occ + high_qul + factor(cat)) AIC = 4686.7						
Cats make good pets	NN	1	-3.542	0.16	-21.96	<0.001
	Age	1	-0.205	0.04	-4.57	<0.001
	Gender	1	-0.225	0.10	-2.24	0.024
	Occupation	1	0.113	0.02	5.11	<0.001
	High qualification	1	-0.130	0.06	-2.15	0.030
	Cat ownership	1	-1.484	0.17	-8.70	<0.001
Model1 <- clm (cat_pets1 ~ factor(n_n1) + age + gender + occ + high_qul + factor(cat)) AIC = 3021.1						

Table 2.9b: The Cumulative Link models (CLM) outputs for Management decision options in NN (reference case only)

Management						
Dependent variables (Management questions)	**Variables in the final model**	**DF**	**SE**	**Coefficient/ Estimate**	**Z- values**	**P-values**
People residing in ecologically sensitive areas should not be permitted to own cats	NN	1	0.10	-1.472	-14.56	<0.001
	Home type	1	0.02	0.056	2.544	0.011
	Cat ownership	1	0.13	0.547	4.23	<0.001
	Model: <- clm (cat_eco ~ n_n) + home_type + factor(cat) AIC = 4672.59					
All cats should wear collar bells or any other anti-predation gadgets	NN	1	0.10	-0.817	-7.834	<0.001
	Occupation	1	0.02	-0.119	-3.195	0.001
	High qualification	1	0.05	0.108	2.215	0.020
	Cat ownership	1	0.13	0.533	3.981	<0.001
	Model: <- clm (cat_collar ~ n_n) + occ + high_qul + factor(cat) AIC = 4405.6					
Cats should not be permitted out at night	NN	1	0.09555	-0.770	-8.056	<0.001
	Cat ownership	1	0.13	0.247	1.932	0.053
	Model: <- clm (cat_night ~ n_n) + factor(cat) AIC = 4808.0					
	NN	1	0.11	-0.562	-5.318	<0.001

Cats should be registered with council.	Age	1	0.04	-0.067	-1.838	0.066
	Occupation	1	0.02	-0.066	-3.525	<0.001
	High qualification	1	0.05	0.206	4.126	<0.001
	Cat ownership	1	0.13	0.407	3.158	=0.002
	Model: <- clm (cat_reg ~ n_n) + age + occ + high_qul + factor(cat) AIC = 4179.3					
Cats should be neutered	NN	1	0.10	-0.268	-2.59	0.010
	employment	1	0.03	-0.116	-3.74	<0.001
	High qualification	1	0.05	0.200	4.079	<0.001
	Home type	1	0.02	-0.071	-3.025	=0.002
	Cat ownership	1	0.13	0.739	5.724	<0.001
	Model: <- clm cat_neut ~ n_n) + emp + high_qul + home_type + factor(cat) AIC = 4531.8					
More effective management of cats is needed	NN	1	0.10	-1.074	-10.973	<0.001
	Occupation	1	0.02	-0.111	-6.035	<0.001
	Cat ownership	1	0.13	0.551	4.138	<0.001
	Model: <- clm (fer_mgt ~ n_n) + occ + factor(cat) AIC = 4227.1					
	NN	1	0.10	-0.043	-0.419	

Euthanizing feral cat not accepted	Age	1	0.04	-0.103	-2.830	0.005
	Gender	1	0.09	-0.244	-2.851	0.004
	Employment	1	0.03	-0.081	-2.577	<0.001
	Occupation	1	0.02	0.115	5.921	<0.001
	High qualification	1	0.05	-0.138	-2.762	0.005
	Home type	1	0.02	0.040	1.710	0.08
	Cat ownership	1	0.13	0.001	0.008	0.9
	Model: <- clm (euth_fer ~ n_n) + age + gender + emp + occ + high_qul + home_type + factor(cat) AIC: 4717.9					
Trap Neuter Return (where feral cats are captured, neutered, and released back into the wild)	NN	1	0.10	-0.442	-4.363	<0.001
	Age	1	0.05	0.174	3.687	<0.001
	Cat ownership	1	0.13	-0.054	-0.414	0.6
	Model: <- clm (tnr ~ n_n) + high_qul + factor(cat) AIC: 4839.8					

Chapter 3

Estimation of pet and free roaming domestic cat populations in Lagos, Nigeria

3.1 Abstract

Obtaining population estimates and knowledge of cat demographics is fundamental to understanding the relationships between people and cats, and therefore the scale of effects of cat predation on wildlife. The population in most developed nations have increased in recent years with a global domestic cat population size estimated at above 600 million. The limited available studies suggest that cat population density in each city is dependent on a range of factors such as the underlying culture of the people, prevailing habitat and the socioeconomic position of residents and can therefore also vary within different localities of urban areas. To my knowledge, I carried out the first work aimed at estimating domestic cat population density in Africa, working in the megacity of Lagos, Nigeria, using questionnaire survey and distance sampling transect approaches. Overall, only 2.8% (77 households) of interviewed households owned at least one cat, while 97.2% (2715) of households did not own cats. Of the cat owning households interviewed 47 (61.0%) owned only one cat, 10 (13.0%) two cats, 5 (6.0%) three cats, 7 (9.0%) four cats, and 8 (10.0%) five or more, amounting to 168 cats. Taking means from each grid survey, 3.3± 1.7% of householders owned cats with an average of 1.96 (95% CI 1.74 - 2.15) cats per cat-owning household. This gives an estimate of 104.3 owned cats per km^2. If the survey is representative, the questionnaire work suggests that Lagos may have a population of 121,784 owned cats. It is notable that while ownership rates of pet cats is low, housing density and higher rates of multiple cat ownership result in higher densities than otherwise expected. Cat density per km^2 based on line transect detection (i.e. largely focused on non-owned cats, and as taken during the day likely to be an underestimate) gave 224.70 cats per km^2 (95% CI 195.7 - 293.7) and the cat population for Lagos (1171 km2) is thus likely to be in the order of at least 229,165 – 343,923 cats, which is lower than for many estimates of cat densities in the developed world.

Our house-to-house survey of owned pet cats shows that female, younger aged cats (1-23 months: 68%) predominate, reflecting high rates of mortality, and rates of neutering were low (~1%). The low level practice of neutering might be due to the absent of any national policy toward containment of cat population in Nigeria.

3.1 Introduction

Studies show that domestic cat population sizes in most developed nations have increased in recent years (Murray et al. 2010; Blancher 2013 and Loss et al. 2013), with a global domestic cat population size estimated at around 600 million (Driscoll et al. 2009). What we know about cat populations is largely the result of studies in the UK, USA, Canada, Australia, and New Zealand. We have little understanding of cat ownership rates in much of the rest of the world, including in Africa. The limited number of available studies tell us that cat population density in each city is dependent on a range of factors such as the underlying culture of the people, prevailing habitat (Özen et al. 2016) and the socioeconomic position of residents (Murray et al. 2010) and can therefore also vary within different localities of urban areas (Hossain et al. 2013; Özen et al. 2016). Cat population density has the tendency to rapidly grow with improved socioeconomic position (Murray et al. 2010) and cat ownership levels are seen to be highest in urban areas (Hanmer et al. 2017), resulting in particularly large local cat populations of the order of hundreds of individuals per square kilometre (Baker et al. 2008; Thomas et al. 2012; Hanmer et al. 2017).

The World Bank record estimates that today over 55% of the world's population lives in cities and that by 2030 the urban population will be more than double its current size (United Nations 2014) with attendant implications for cat population sizes, if countries follow patterns seen in the limited range of countries studied. Africa's most populous country, Nigeria, is projected to experience high rates of urban expansion, concentrated along the country's coastline (d'Amour et al. 2017). Lagos is one of the fastest growing megacities in the world (Investmentmonitor, 2021), with flourishing socioeconomic standards compared to other major cities in Africa. Pet cats as well as feral cats, are common (Udofia, pers. obs.). Domestic cats have high reproductive capacity (Courchamp et al. 2003; Bonnaud et al.2007) and in the tropics year-round reproduction can be achieved with sufficient access to food and conducive habitat (Fitzwater, 1994; Lessa & Bergallo, 2012).

Domestic cats, apart from their role in pest control, are companion animals, bringing physical and psychological benefits (Raina et al. 1999; McConnell et al 2011) such as reduced loneliness (Castelli et al. 2001), reduced risk of heart problems (Anderson et al 1992), and provision of emotional support (Stammbach & Turner 1999), overall leading to reduced hospital visit rates (Siegel 1990; Headey 2002). However, cats are also associated with toxocariasis, toxoplasmosis, asthma, and other allergies (Gethings et al. 1987; Deplazes et al. 2011; Aegerter et al. 2017). There are policy concerns as well as health and social issues, as cats, generalist and opportunistic predators by nature (Barratt 1997a; Thomas et al. 2012; Loyd et al. 2013; Hanmer et al. 2017; Dicman & Newsome, 2015) have been identified as one of the most invasive predators by the IUCN (Lowe et al. 2000) and identified as one of the greatest threats to fauna biodiversity and conservation (May 1988; Barratt, 1997b, 1998; Wood et al. 2003; Baker et al. 2005, 2008; Dauphine and Cooper, 2009; Van Heezik et al. 2010; Medina et al. 2011; Thomas et al. 2012; Bonnington et al. 2013; Loyd et al. 2013, Kitts-Morgan et al. 2015; Doherty et al. 2016; Hanmer et al. 2017). Cats adversely affect wildlife populations directly through predation and indirectly through risk-aversion (fear) effects and other sub-lethal effects (George 2010; Bonnington et al. 2013). Though it is still unclear if these effects have population-level consequences for their prey (Baker et al. 2005, 2008; McDonald et al. 2015; Hanmer et al. 2017). Identifying methodologies socially acceptable to manage feral or non-owned and free-roaming domestic cat populations thus comes with challenges (Levy & Crawford, 2004; Flockhart et al. 2016) and hence worthwhile to work from an informed position backed by robust estimates of cat population size when dealing with issues of cat predation management.

Knowledge of the population density of pet and feral cats is thus crucial, as regulatory policy development by government or agencies must rely on accurate data for decision making. This also applies to developing appropriate mitigations (Aegerter et al. 2017) and engaging cat owners (Thomas et al. 2014; Elizondo and Loss. 2016). Studies that aim to estimate owned cat population sizes have used methods ranging from relatively simple estimation methods which calculate the mean number of cats per household multiplied by the number of households in the area and human density in the area multiplied by number of cats per human (Slater et al. 2008), to more complex statistical models (Nassar & Fluke, 1991) or probability estimates with added advantages of precision measures and providing 95% confidence intervals for estimates (Murray et al 2010), in the calculation of the estimated population size and density of pet cats (Downes et al 2013). Nassar and Mosier (1991) used statistical modelling to predict the population size of domestic cats and dogs in the USA and Baldock et al. (2003) did same for domestic cats in Australia. This statistical modelling supports relatively simple approaches as they have found relationships between numbers of people living in a house and the probability of owning a cat (Nassar and Mosier 1991, Westgarth et al. 2007; Murray et al. 2010).

However, such approaches will not work for estimating the population size of feral or non-owned domestic cats, where a variety of other factors will come into play as feral or non-owned domestic cats have different activity patterns and ranges (Clancy et al. 2003; Horn et al. 2011; Flockhart et al 2016). Estimating the population size of non-owned cats in an area will rely on basic ecological census techniques. In essence, there are two main methods for estimating cat population density, each with strengths and weaknesses. First, population size can be estimated using mark-recapture techniques (Krebs, 2009). Actual capture of cats is not essential where cats can be safely identified as individuals by their markings, but this technique relies upon multiple visits to locations to be effective, but when properly performed, this technique provides reliable estimates of local population densities. Second, distance sampling can be used to estimate population sizes. This approach allows for greater coverage but relies on some key assumptions being met (Buckland et al. 2001; Krebs, 2009). It assumes that animals are randomly distributed, but this assumption is likely to be violated in a city. Nevertheless, this approach is more tractable as an initial approach to estimating cat population densities in an urban area. Population densities of cat from studies have shown quite a wide margin in range from 0.03 cats/km^2 to 2800 cats/km^2 for very poor to more favourable conditions (Denny and Dickman, 2010) and a 0.44 cats/km^2 for a sub-Antarctic environment (Say et al., 2002) and values for urban setting ranging to some hundreds of cats per square kilometre (Baker et al., 2005; Lessa and Bergallo, 2012; Thomas et al., 2012; Carvelli et al. 2016).

In this chapter I report the first estimates of domestic cat population density in a city in Sub Saharan Africa. Two approaches are used. First, a questionnaire approach is used to estimate the numbers of owned cats.

Second, a distance sampling transect approach is used to estimate overall cat population density and thereafter compare the population estimates from both to examine if the distance transects sampling methods employed are adequate for estimating free-roaming cats in urban areas and hence to infer likely numbers of non-owned cats in the study areas. Understanding the population size of owned and non-owned cats is the foundation of being able to consider the relationships between people and cats, the scale of effects of cat predation on wildlife, and to provide the basis of a framework to support future research endeavours in managing the predatory effects of domestic cats on biodiversity.

3.2 Study Area and Methodology

3.2.1 Study area

This study took place in the metropolitan area of Lagos, which is a mix of mainland, coastal peninsular regions, and islands with a total area of 1,171.28 km² and with an estimated population of 21m people (Rosenthal 2012; City Population, 2015). Lagos is the largest city and financial centre in Africa (Investment monitor, 2021). Lagos is also among the top ten of the world's fastest-growing cities and urban areas (City Population, 2015).

The city is located on the southwest of Nigeria (6°27′ 14.65″ N, 3°23′ 40.81″ E). The selected study area is Lekki peninsular located in the southeast of Lagos, Nigeria and within four representative locations in this area which includes Lekki Conservation surrounding settlements of Alpha – Beach and Lafiaji-Barbwire, Owonikoko-OkunAjah and Ikota which is a few kilometres from the conservation centre. The developments are predominantly mixed density residential areas comprising high rise multiple apartments and triplex to duplex terrace town houses, with mix of detached and semi-detached duplexes and bungalows with some temporarily movable residential structures and caravans. The city of Lagos is located at the Southwestern Geopolitical zone of Nigeria. The environment is generally that of wetland being influenced by a long-wet season from April to October and a dry season from November to March (Ogundele, 2012). The prevalent natural vegetation is that of swamp forest of the fresh water and intermix of mangrove swamp forest with temperature and annual rainfall ranges of 29-34^{o}C and 1381mm to 2733mm respectively (Ogundele, 2012). Lekki Conservation Centre covers an area of 78 hectares and helps provide cover for the wetlands which is inhabited by a high diversity of mammals, birds, reptiles, amphibians, insects, and many other life forms (Talabi 2016).

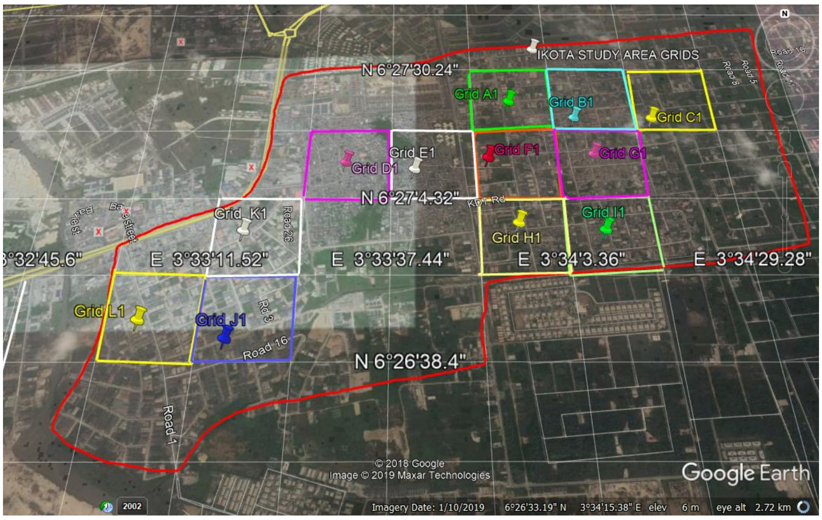
3.2.2 Sample grids selection and data collection

Randomly chosen (by lot casting) sample grids of 400m by 400m were set using the universal gridding system on Google Earth pro map. For each study area, lots were cast against the numbered grids and the randomly chosen grid numbers from the lots were used for choosing transects in the population study. Transect lines were chosen using existing roads and street networks. We carried out a questionnaire survey of domestic cats in all houses along both sides of the transect lines. Test data collection commenced in the week of 16/12/2019 with the follow up data collection campaign proper starting in January 2020. Questionnaires were administered from paper hard copies and using a Crowdsignal application (Crowdsignal 2008) questionnaire saved on iPads synchronised to an online survey using the link: https://pawrg.polldaddy.com/s/global-population-survey. Printed hard copies were left with some household members who were not ready to participate immediately, which were collected later and inputted to the iPad.

Questionnaires were used to explore the number of cats owned, the sex and age of the cats, whether they were neutered, the number of people in their household and what number are adults, the residence type, whether they feed their cat and how many cats wear collar with a bell. Cats were registered and photographed when cats were present at the time of interacting with the owner for questionnaire filling.

We additionally estimated the density of domestic cats on the streets using the same transect lines and based on linear transect methods (Buckland et al., 2001) to complement the cat population survey outcome, to provide insights into the number of non-owned cats in the study sites. Measurement along the transects and coordinates were taken using the Etrex 10 GPS device and confirming the sizes on the map by measuring using the ruler tool on the google earth. Equal transect lengths of 1,200m were taken per grids for the transect lines combine length (figure 1 & 2). Each transect was walked two times (morning and evening), and one of these periods was repeated randomly.

Figure 3.1: Ikota study area and associated grids



These are the selected accessible grids for Ikota study area used in the random selection for the lots casting. Out of the twelve accessible grids, five were randomly selected (Grid A, D, G, H and J). The same process was completed for the other three study areas.

3.2.3 Data Analysis

Several methods exist that can be applied to the question of estimating the size of pet and free roaming cat populations. This study used a general cross-sectional study design and employed the use of questionnaires along selected transect lines within the random sample grids from within the specified study areas by a door-to-door sampling method and sighting along transect lines.

The questionnaire survey allowed cat population density to be calculated in 20 randomly selected grids in the four study locations, with residents in more than 2700 houses interviewed. Cat density was calculated as D = TF*P*Cx (after Thomas et al. 2012) where T is the total number of houses recorded for the total transects length in a particular grid, F is a factor relating T with the approximate total number of house in the grid, P is the proportion of households containing cats and Cx is the measure of the mean number of cats per cats-owning household. Since there is no database with the number of houses in a particular grid, we approximated the total number of houses in the grids by calculating it as a direct function of the total number of houses recorded for total length of transects in a particular grid. We obtained the relation factor (F) by randomly picking a grid per location for the four locations and counting the total number of houses in those grids using Google Earth (Figure 2.3 is Ikota grid G1 for example), I then established a relationship factor per location by dividing it with the total number of houses recorded along the transect in the corresponding grids, so that F per grid = Hg/T; where Hg is the total number of houses in the grid. The mean value (Fix) derived from the individual location's relation factor was then applied in all other grids to calculate the approximate total number of houses in the grids and thereafter used in calculating the cat density values per grid (Table 3.1).

Table 3.1: Relationship factors (F) per grid and the mean factor Fix used in calculations.

Location/site	**Grid name**	**Number of houses in grid (Hg)**	**Number of houses along transects (T)**	**Relation factor (F)**	**Mean of F**
Ikota	**G1**	**602**	**132**	**4.56**	
Owonikoko-OkunAjah	**E2**	**598**	**128**	**4.67**	
Barbwire	**C3**	**822**	**178**	**4.62**	
Alpha Beach	**E4**	**854**	**185**	**4.62**	
					4.62

Cat density was additionally calculated using the Haynes estimator (Haynes 1949; Krebs et al. 2017) for cats sighted along the transects in the randomly selected grids. Cat density was calculated as $DH = n/2L\ (1/n \sum 1/ri)$ where DH is the Haynes estimator of cat's density, n is the number of cats seen, L is the total length of the transect and ri is the sighting distance to each cat. For grids that the Haynes estimator were not applicable due to the critical assumption that the angle of sightings averages 32.70 as inherent in the Haynes estimators assumptions (Haynes 1949; Krebs et al. 2017), the modified Haynes estimator was used and calculated as $DMH = c\ DH$ where MHD = modified Hayne estimator, HD = Hayne estimator, c = correction factor = $1.9661 - 0.02954\ \theta x$ and θx = mean sighting angle for all n observations (following Burnham and Anderson 1976). Correlation analyses was used to investigate associations between density of cats, the number of owned cats, and the independent variable(s) of house density.

Figure 3.2 A. Ikota Grid G1 (N6*27’17.28’’; E3*34’3.36’’) randomly picked in the calculation of correction factor (F) for the approximate total housing density in a grid.

3.3 Results

Data were collected from a total of 2,792 respondents which are the households and being 88% of household along the transects and of which 54% (1,496) were women and 46% (1,295) were men responding and the most frequent age bracket was 26-35 (33%). Overall, 77 (2.8%) interviewed households did owned at least one cats while 2715 (97.2%) households did not own any cat . Of the cats owning households interviewed 47 (61.0%) owned only one cat, 10 (13.0%) two cats, 5 (6.0%) three cats, 7 (9.0%) four cats, and 8 (10.0%) five or more, counting to 168 cats. Younger aged cats (1-23 months: 68%) predominate, and rates of neutering were low (~1%). Single cats per household (60%) dominated the numbers of cats per household and the residence types with temporary building/Caravan (40%) of residence type. More than 88% of respondents that owned cats allow their cat free access outside and pest control ranked the highest reason for keeping cats.

Within all the grids surveyed, a mean value of 3.3± 1.7% of householders owns cats with an average of 1.96 (95% CI 1.74 - 2.15) cats per cat-owning household (Table 3.2). The cat density per square km across the sampled 20 grids in the four locations based on house-to-house survey is 104.3 cats per km2 (95% CI 83.95 - 124.65: Table 3.2).

Table 3.2: Estimated cat density based on house survey in 20 sample grids of 0.4km² areas in Lagos.

Location-Grid	Total nos of houses on transects	Total nos of houses on transects (responding houses) [nos of houses with cats]	TF (Approximate total nos of house per grid)	Nos of cats seen at home	Mean number of cats per cats-owning household.	Proportion of household containing cats (P)	CATS Density (D = TF*P*Cx) per 0.4 square km	CATS Density per square km
Ikota-A1	107	107 (75) [8]	494.34	13	1.625	0.075	60.06	150.15
Ikota-D1	105	105 (90) [5]	485.1	13	2.167	0.048	50.05	125.13
Ikota-F1	84	84 (74) [3]	388.08	8	2.667	0.036	36.96	92.4
Ikota-G1	130	130 (115) [3]	600.6	7	2.333	0.023	32.34	80.85
Ikota-H1	168	168 (128) [7]	776.16	17	2.429	0.042	78.54	196.35
Owoni-OkunAjah-A2	171	171 (150) [4]	790.02	10	2.500	0.023	46.2	115.5
Owoni-OkunAjah-C2	225	225 (193) [5]	1039.5	7	1.400	0.022	32.34	80.85
Owoni-OkunAjah-E2	130	130 (119) [3]	600.6	4	1.333	0.023	18.48	46.2
Owoni-OkunAjah-G2	163	163 (146) [4]	753.06	6	1.500	0.025	27.72	69.3

Owoni-OkunAjah-I2	124	124 (113) [3]	572.88	5	1.667	0.024	23.1	57.75
Barbw_B3	111	111 (94) [4]	512.82	11	2.750	0.036	50.82	127.05
Barbw_C3	178	178 (158) [3]	822.36	5	1.667	0.017	23.1	57.75
Barbw_H3	160	160 (150) [12]	739.2	8	1.600	0.075	88.704	221.76
Barbw_I3	203	203 (188) [2]	937.86	5	2.500	0.010	23.1	57.75
Barbw_J3	176	176 (152) [6]	813.12	8	1.333	0.034	36.96	92.4
AlphaB-A4	144	144 (122) [5]	665.28	7	1.750	0.035	40.425	101.06
AlphaB-D4	110	110 (97) [5]	508.2	9	1.800	0.045	41.58	103.95
AlphaB-E4	175	175 (154) [3]	808.5	7	2.333	0.017	32.34	80.85
AlphaB-H4	241	241 (215) [7]	1113.42	11	1.833	0.029	59.29	148.23
AlphaB-I4	163	163 (151) [4]	753.06	7	1.750	0.025	32.34	80.85
mean value				168	1.947	0.033	41.72	104.31
STDEV					0.464	0.017	18.58	46.44
CI (95%)					0.20	0.01	8.14	20.35

Cat density per km^2 based on cats detected on transects gave 224.70 cats per km^2 (95% CI 195.7 - 293.7: Table 3.3) and was greater than that based on the house-to-house survey. If data is representative, result suggest that for every observed domestic cat there are equivalent numbers of free roaming unowned cats outside. The population density of cats was distinctly low for the low income residential neighbourhood around the ocean beach front of Owonikoko-Okunajah sample grids and those of Alpha beach (Table 3.3; Figure 3.5). The total free roaming cat population estimate for the City of Lagos is therefore an approximate 286,538 (95% CI: 229,171 – 343,904) cats.

Table 3.3: Estimated cat density km^{-2} based on line transect sighting in 20 0.4km^2 sample grids in Lagos.

Location-Grid	**Number of Cats sighted on transects**	**Mean Angle of sight (θx) degrees**	**Haynes estimator of cat's density DH = n/2L (1/n ∑ 1/ri)**	**(correction factor = 1.9661 - 0.02954 θx)**	**modified Hayne estimator Dhm = c D**
Ikota-A1	14	30.56	208.107	1.063	221.320
Ikota-D1	14	30.55	510.883	1.064	543.471
Ikota-F1	13	30.30	304.171	1.071	325.779
Ikota-G1	7	31.67	127.907	1.031	131.829
Ikota-H1	11	32.67	203.484	1.001	203.713
Owoni-OkunAjah-A2	9	36.29	117.225	0.894	104.825
Owoni-OkunAjah-C2	9	35.38	125.898	0.921	115.968
Owoni-OkunAjah-E2	4	32.00	61.930	1.021	63.219
Owoni-OkunAjah-G2	10	35.20	170.537	0.926	157.967

Owoni-OkunAjah-I2	7	30.43	146.555	1.067	156.409
Barbw_B3	9	32.75	269.486	0.999	269.127
Barbw_C3	7	32.29	228.402	1.012	231.229
Barbw_H3	12	32.20	331.258	1.015	336.198
Barbw_I3	6	34.60	212.787	0.944	200.875
Barbw_J3	9	34.11	352.823	0.958	338.166
AlphaB-A4	10	32.22	324.519	1.014	329.145
AlphaB-D4	12	32.89	314.008	0.995	312.300
AlphaB-E4	10	31.00	306.289	1.050	321.714
AlphaB-H4	12	31.00	294.779	1.050	309.624
AlphaB-I4	8	32.29	218.323	1.012	221.026
mean value	**193.00**				**244.70**
STDEV					111.78
CI (95%)					48.99

3.4 Discussion

Population estimates and knowledge of cat demographics is fundamental to understanding the relationships between people and cats, and the scale of effects of cat predation on wildlife or in disease transmission. My free-roaming cat population estimate for the City of Lagos is the first empirical estimate of cat population size in Sub Saharan region of Africa, and therefore provides a baseline for future research endeavours.

Our house-to-house survey shows that rates of pet cat ownership in Lagos is relatively low, with less than 3% of households owning cats, which contrasts with typical rates of cat ownership of around 25% of households found in Europe, North America and Australia (Sims et al. 2008; Thomas et al. 2012; Murray et al. 2010; Toribio et al. 2009). Negative associations of cats with witchcraft, which remains high in Nigeria

(Chapter 2) plays a part in this. Here, most owned cats were young (1-23 months: 68%) and females were more prevalent in the population structure, and this is younger than found in a study from Italy, where there significantly more older cats in the population, including ~5% of over 15 years of age (Carvelli et al. 2016). The younger feline population dominance of the population spread is typical of high fertility species such as domestic cats (Thrusfield, 1989; Courchamp et al. 2003; Bonnaud et al. 2007; Carvelli et al. 2016), but may also reflect the reduced amount of veterinary care provided, and higher risks of mortality in Lagos (see Chapter 2). The higher ratio of female cats to male counterparts may be due to high male mortality caused by increased fighting for territory protection seen in males (Toribio et al. 2009; Carvelli et al. 2016). Changes in attitudes to pet care may quickly result in rapid increases in population growth rate in the future as fertility rates fall.

The reported percentage of neutered cats (1%) in this study is among the lowest in studies that also examine cat demographics, were we have values ranging from 45% in Italy (Slater et al. 2008); 70.5% semi-rural area Central Italy (Carvelli et al. 2016); 76.6% in Ireland (Downes et al. 2009), 96% in Reading, UK (Thomas et al. 2012) and 97.3% in Sidney, Australia (Toribio et al. 2009) etc. This low level practice of neutering might be due to the absence of any national policy toward containment of cat population in Nigeria and the overwhelming lack of information and awareness on the part of the populace of the predatory impact of cats and association with zoonosis, a lack of local veterinary care for domestic animals and the costs associated with such interventions.

It has been observed that the approach of using multiple methods to estimate population densities for cats is considered the most robust approach (Brikner, 2007; Lessa and Bergallo, 2012). Individual methods have their inherent short comings and typically the house-to-house cat survey is very effective but will likely always underestimate the cat population density, as it does not consider un-owned free roaming cats, while transects will under record owned cats, which tend to stay close to residences (Chapter 4) and unowned cats, which roam more freely at night (Blackburn et al. 2004; Hilton and Cuthbert 2010; Palmas et al. 2017;). Again, it is difficult to ideally estimate cat population due to possible information inconsistences from cat owners and the fact that street cats have no population control, among other uncertainties (Brikner, 2007), but this study presents a first attempt to calculate cat population densities in an urban area of Sub Saharan Africa.

Cat densities recorded in this study from the two methods were 84-125 cats/km^2 and 196-294 cats/km^2 for house to house surveys and line transect methods respectively, falls within the ranges of recorded cat densities from 0.03 cats/km^2 to 2800 cats/km^2 for very poor to more favourable conditions (Denny and Dickman, 2010) and were particularly comparable to other urban setting studies recorded cat densities of 229 cats/km^2 (Baker et al. 2005; Bristol, UK); 2300-2800 cats/km^2 (Mirmovitch 1995; Jerusalem, Israel);

132-1580 cats/km^2 (Sims et al. 2008; Britain); 248-445 cats/km^2 (Thomas et al. 2012; Reading, UK). The lowest cat densities in this study are associated with areas with households with very low income and where homes are predominately temporary accommodations of caravan settings. These areas are mostly concentrated along the beachfront that straddles the Atlantic Ocean and the Lekki peninsula, where because of the mode of living, poverty and low levels of education, the possibilities of cat killing for meat are high (see Chapter 2).

Taking the mean cat densities values for the house-to-house survey and the line transect sighting for the low and high ends value, the cat population for Lagos (1171 km^2) is thus in the order of 122,143 – 286,538 cats. The cat density/km^2 value range for Lagos as seen from this study is on the lower end of recorded values for an urban setting and this is insightful as it paints the picture of the effects of the strong repugnance towards cats regarding association with witchcraft and negative forces inherent in the attitude of Nigerians, the strong acceptance of cat meat eating among the populace and the widespread killing of cats for traditional medicine in this part of Nigeria.

3.5 Conclusion.

Having up to date and reliable estimates of free roaming cat population size and their demographics is central to managing cats from public health, nuisance control and conservation perspectives. Our study finds that cat densities in Lagos are lower than those recorded in other urban settings, but are still substantial, and given the rapid population growth seen in Lagos; the threats posed by cats to wildlife in the region are likely to increase.

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Chapter 4

Roaming behaviour of pet cats Felis catus in urban habitats in Lagos, a modern megacity

4.1 Abstract

Cats are successful generalist predators and opportunistic hunters and people impression are tilting towards the indictment of free roaming cats as having significant impact on the environment. As human population increases with expanding urban developments, cat population has the tendency to also grow rapidly as one of the world's most common pets and are increasingly encroaching on key wildlife sanctuaries. Notwithstanding it is evident that little is known about cats ranging patterns as few studies have been done so far and non in Sub Saharan Africa.

Study assesses the core and home range size of pet domestic cats in a previously unstudied region, trying to understand how environmental features (season; time of day; access to prey; type of home) and individual features (cat age, sex, neuter status) affects cat ranging behaviours.

Fifty four cats recruited from houses within the immediate catchment of the Lekki conservation area and from households 3 to 4km away from it were fitted with GPS trackers to monitor and record their movement data. Over the period inclusive of both the wet and dry season, home range sizes ranged from 0.07 ha to 10.443 ha at 95% KDE for all cats, with a mean home range size (95 % KDE) of 1.381. ha and maximum ranges size of 1.994 ha (98% KDE). The absolute mean maximum daily area ranged by a cat was 13.18 ha, an equivalent of 230 m diameter for a circular area and a radius of 115m, with individual cats travelling much further.

Study detected seasonal differences in the home range areas where we observed cats ranging further in the dry season and the he difference in the ranging areas between night and day was significant with cats seen to range further in the night than in the day. Numerically the home range was largest for the male cats as against the female cats though not significantly difference. Ranges found here are similar to the ones in other studies in UK, USA and Australia.

Cats with larger home ranges could potentially inflict more damage on wildlife and our study demonstrates buffer zones in the order of >300 meters would be effective in safeguarding important wildlife habitats in tropical habitats, just as much as in other parts of the world.

4.1 Introduction

In urban and suburban areas, free-roaming cats are far more abundant (Thomas et al. 2014) and greatly exceed the density of other predators combined (Liberg et al. 2000) and thus are the most important predators of many terrestrial vertebrates in urban ecosystems (Lloyd and Hernandez 2012)**.** We have a good understanding of the history of the evolution, domestication and dispersion of cats globally (Denny et al. 2010). Sepell's (1994) work suggests that the subspecies *Felis silverstris lybica* (the African wild cat) is the most likely ancestor of modern-day cats and is known to have lived and foraged near human settlements for thousands of years and combined with a more docile disposition than other wildcat subspecies, this resulted in the emergence of the relationship that exists today between domestic cats and humankind. With a global domestic cat population size estimated more than a decade ago at around 600 million (Driscoll et al. 2009), Lepczyk et al. (2010) highlights the increased trending to keep cats as pets and the possibility of cats soon overtaking dogs as the preferred pet by humans. In Britain alone we already have an estimated population of over 9.5 million domestic cats (Roberts & Browne 2015) and growth in pet cat numbers is seen in many other countries of the world (Murray et al. 2010; Blancher 2013 and Loss et al. 2013). Ownership levels have been seen to be highest in urban areas (Hanmer et al. 2017), resulting in large local cat populations around the semiurban and urban settings, with many hundreds of cats found per square kilometre in some areas (Baker et al. 2008; Thomas et al. 2012; Hanmer et al. 2017; Chapter 3).

However, domestic cats are considered to be one of the greatest threats to fauna biodiversity and conservation (Churcher & Lawton, 1987; May, 1988; Barratt, 1997b, 1998; Wood et al. 2003; Medina et al. 2011; Doherty et al. 2016; Hanmer et al. 2017). It has been argued that *Felis catus* exacts a huge toll on small birds and mammals (Denny and Dickman, 2010) and are considered the primary threat to over 8% of threatened reptiles, birds and mammals (Medina et al. 2011; Doherty et al. 2016; Hanmer et al. 2017). Specifically, Doherty et al. (2016) argued that cats introduced to islands have caused the extinction of 63 animal species including 40 birds. Denny et al. (2010) documents that 35 vulnerable and endangered bird species, 36 mammal species, seven reptile species and three amphibian species are thought to be adversely affected by feral cats. Apart from the negative predation impact on fauna and in particular small mammals and birds (Woods et al. 2003; Loss et al. 2013), cats are also carriers of zoonosis, parasites and pathogens which cause diseases when in contact with other pets, livestock and human beings (Mahlow and Slater) Cats are confirmed as the major route for *Toxoplasma* infection of both humans and animals (Han et al. 1999). The possibility exists for free roaming cats to act as secondary transfer conduits for avian influenza virus through direct or indirect contact with wild birds and epidemiological investigations has also been confirmed (Moon et al. 2013).

The size of a cat's home range can help predict the extent of its impact on native wildlife (Kitts-Morgan et al. 2015; Hanmer et al. 2017). A variety of factors can affect cat ranging abilities and behaviours (Pirie et al. 2022) these includes being stray, wearing or not wearing a collar bell, cat age, cat sex, and wearing a bell (Warner and Heske 2011; Coughlin and van Heezik 2014; Hall et al. 2016). Other studies have suggested where cats live (urban vs peri-urban; Hanmer et al. 2017; Pirie et al. 2022) and cat density (Barratt 1997; van Heezik et al. 2010) as influencing range size. Studies on cat tracking in four different cities suggest that cats rarely utilise natural areas as seen in the studies in Albany pine bush forest (USA; Kays & DeWan 2004), Australian heathland (Meek 2003) and New Zealand native bush (van Heezik et al. 2010), but this is not so in the UK (Pirie et al. 2022).

Studies on home range sizes of free-ranging domestic cats have been carried out in the USA (Morgan et al. 2009), Australia (Barratt 1997a; Meek 2003), New Zealand (Morgan et al. 2009; Metsers et al. 2010; van Heezik et al. 2010), and recently in the UK (Thomas et al. 2014; Hanmer et al. 2017; Pirie et al. 2022). However, in Africa there have been very few such studies on cats ranging behaviour, with the notable exception of South Africa (George 2010; Pillay et al. 2018), which is not representative of great regions of the continent. This lack of very basic data is very challenging as it is impossible to estimate the severity of the problems caused by cats and to proffer solutions without this basic understanding of roaming behaviour in the region. Furthermore, cat ranging behaviour will be associated with their hunting behaviour, as the movement of cats into new habitats away from their owner's homes will affect the abundance and diversity of prey that they can kill. While this is self evident, there are very few studies that link pet cat prey return and their roaming behaviour (Pirie et al. 2022).

To address this knowledge gap, this study was conducted in Lagos, Nigeria, West Africa, where I attempt to estimate the home range size of free-ranging pet domestic cats. Using GPS tracking, I ask what the home range size is of pet cats in four representative areas. Alpha beach, Barbwire, and Owonikoko are around the Lekki conservation reserve area and another area (Ikota) is about four kilometers away from the nature reserve area, all in Lekki-Lagos, Nigeria and I compare (1) factors influencing core and home range sizes, (2) day versus night range sizes, (3) dry and wet season ranges and (4) broad habitat use. In this study we also seek to know how the availability of natural (non-urban) habitat of the Lekki conservation areas affected (a) the range and habitat use; (b) where tracked cats returned prey, are there differences in habitat use?

4.2 Methods

4.2.1 Study area

This study was carried out in Lekki, Lagos, Nigeria, Africa and located on the general grid reference (6°27' 14.65" N, 3°23' 40.81" E). There are two seasons in Lagos, a wet season which lasts from April to October and a dry season from November to March. Lagos has a mean annual rainfall of approximately 1,657 mm with a monthly average maximum temperatures fluctuating from 28.6 °C in July through August to 33.7 °C in February through March (Ojeh et al. 2017). The city of Lagos is the most densely populated city in Nigeria with mostly mixed density residential areas with total city area of 1,171 km² and with an estimated population of 21m people (Rosenthal 2012; City Population, 2015). The city of Lagos is located at the

Southwestern Geopolitical zone of Nigeria. The study area was chosen due to its proximity to the Lekki Conservation centre, a large biodiversity conservation park in the centre of the Lekki stretch which covers an area of 78 hectares (Talabi 2016).

Four locations within the Lekki Conservation catchment area (Fig.4.1) were selected for the study; Alpha-beach, Barbwire, and Owonikoko, which are mostly mixed density residential areas around the Lekki Conservation centre and Ikota (Fig.4.1) which is 3-4 km away from the conservation area. All are in the Eti Osa Local Government Area.

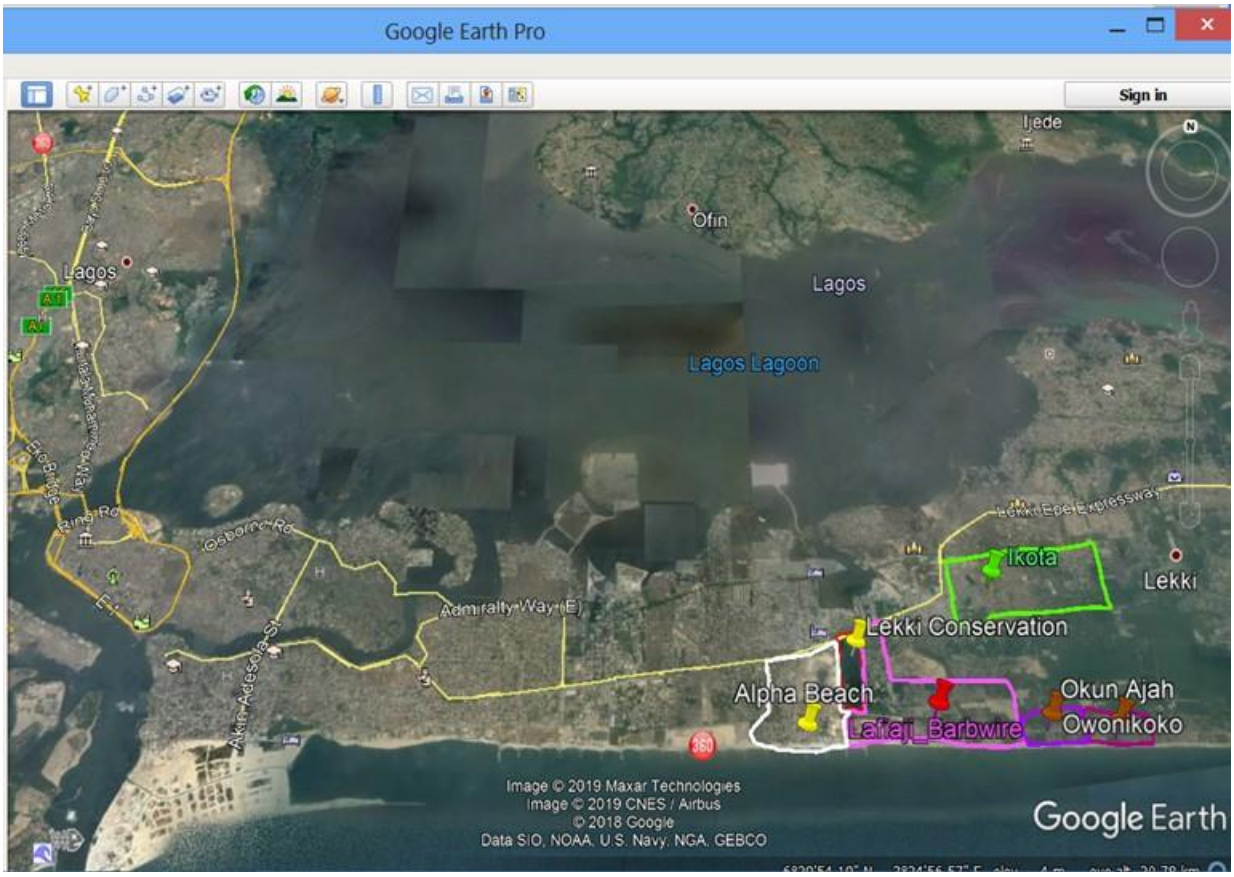

Figure 4.1: Location site marked lime colour is Ikota 3-4 km away from the conservation and L-shape marked magenta is Lafiaji barbwire, red bordered line to it is the Lekki conservation center, white is Alpha beach, darkorchid is Okunajah, purple is Owonikoko which are the areas within the conservation.

4.2.2 Data collection

Cats were recruited during the door-to-door questionnaire survey (Chapter 2). This study was approved by the School of Biological Sciences ethical review committee with reference number SBS18-19 06 University of Reading. To meet ethics requirements, only cat owners who were above 18 years of age were included. Referral of participants friends, relatives and neighbours who own cats were being encouraged to take part in the sampling exercise. Cats were recruited from houses within the immediate catchment of the conservation area and from households 3 to 4km away from the conservation area. Owners were asked to fill in the following information about their cats: cat age, sex, neutered or intact, weight, cat colour, and hair length, as the actual breed of the cat was not considered, recent medical information/treatment, whether cats were left outdoors all day or night only or both, if they feed their cat or not and whether cats had ever worn bells before now. Only cats that were over a year old and in good health to be sure they are fit and weighed 2kg and above were used to ensure the tracker would not weigh more than 2% of their body weight (Coughlin & van Heezik 2015).

Householders were asked to take records of all prey items returned home by their cats during the tracking period. Also, cat owners were asked if they have a garden, if they feed wildlife in their gardens and how many cats visited their garden. Cats wore collars for seven days to enable cats to get used to them before tracking commenced, and cat owners were advised to monitor their cats to ensure their well-being. If there were no signs of discomfort during this period then the cat was kept in the main study.

4.2.3 Cat tracking

GPS tracking models i-GotU (Mobile Action Technology, Taiwan) which are 44.5 x 28.5 x 13mm in dimensions, powered by a lithium battery and weighing 20g were used in this study. All cats used were between a year and five years old, had free access to the outside of owner’s house, were healthy and weighed over 2 kg. Despite the fact the trackers are waterproof, for extra protection from heavy rainfall the trackers were wrapped with cling film before being inserted into the blue gel case. Black insulation tape was applied to the central bar of the case to strengthen the trackers and wrapped around both the device and case to prevent removal from the gel case. The case was attached to the collar and turned on to track the cat.

The GPS receivers were attached to a quick release collar for safety purposes which can easily be removed or broken off in case the cat gets caught by the collar. Cat’s owners were advised to monitor their cats when the GPS trackers were worn for the first trial period of one week and subsequently to be sure cats were doing well and that trackers should be removed from cats immediately if it becomes restless or show signs of stress. The GPS trackers were set to obtain a fix once every 15mins. Cats were tracked for a period of ten days per month starting from November 2018 and continues until October 2019 to cover one full cycle of the dry and wet seasons.

Cats were sometimes tracked twice a month to make sure cats which were not seen during the first tracking for that month were tracked in the second round. They were allowed a five day cat resting period and battery charging in-between the ten days tracking interval. Trackers lost at the early stages of the tracking were replaced once reported by the cat owners. Whenever lost trackers were recovered, the download from replaced trackers were combined (Coughlin & Van Heezik 2014).

The nature of the habitat the cats uses can impact the accuracy of the GPS fixes. Earlier studies using this device which is also used in this study have found positional errors of 10.03m when viewed from the definite location where the device has a clear view to the satellites and close to 29.96m when placed under an adult tree with a relatively open canopy, although these errors can be greater where thick vegetation occurs (Hanmer et al. 2017). GPS fixes were downloaded from the device and checked using GIS (Quantum GIS, version 3.4.0) to compare the fixes throughout the tracking period (Hanmer et al. 2017). Excessive differences in altitude between GPS fixes were used to determine these errors (following Moen et al. 1997). Points which were above 500m from where the cat lives and with big differences in altitude were considered outliers and were removed using toggle editing on the toolbar.

4.2.4 Data Analysis

Home range approximation

Home range has generally been accepted to imply an area usually covered by animal in its normal routines of foraging, resting and reproducing. This concept of the animal home range is based on Burt's (1943) definition, and although irregular long-distance movements may occur these are not always considered as part of the animal's normal home range. In this study, 50% KDEs were used as a measure of the cat core ranging area, 95% KDEs were used to measure ranging area and 100% MCPs were used as a measure for maximum ranging area of the free roaming cats. 50% MCP and 95% MCP were also calculated to allow for comparisons with previous studies (Metsers et al. 2010; Van Heezik et al. 2010; Thomas et al.2014; Hanmer et al. 2017) (Table 4.1 Appendix -1).

Data recorded from each study area were classified as being made during the day or night, the day being calculated from 6:00:00 - 17:59:00 and the night hours calculated from 18:00:00 - 05:59:00 for all cats. There were few minutes/seconds differences in time calculated for day and night for all cats and all locations. The averages for 50%, 95% and 100% MCP's were calculated from the mean for each day sampled. The core kernel density estimate range (50% KDE) and home kernel density estimate range (95% KDE) were calculated from all the fixes for each cat for dry season separately (projection:WGS84 / UTM zone N32) and combined using the "adehabitatHR" package in R (R Core Team 2018, version 3.5.1) and same for the wet season. Farthest distance journeyed from home was measured from the cat owner's residence to the maximum point in their 95% KDE home range approximation. ESRI shape files of the KDEs were estimated and saved using the "maptools" package. Means of the 50%, 95% KDEs and the 100% MCP per site were calculated for the locations. Distance from the middle of the cat owner's home or business premises to Lekki conservation area was measured to observe how far the cats goes near or into the conservation area to help understand their prey return rates and prey type. A comparison of the differences in the total home range sizes per cat across the study sites was done using a Kruskal-Wallis test. Based on the distribution of the data, a Paired t-test or Wilcoxon test was used to calculate the mean/median of home range sizes of the cats across the study sites for day versus night and dry versus wet seasons.

A generalized linear mixed model was run for all tracked cats in R (R Core Team, 2018, version 3.5.1, package 'lme4'), with home-range size as the response variable and site as a random factor. Factors which have been found by other studies to affect home range were included as independent predictor variables; cat age (rounded to nearest year) and sex (Hall et al., 2016), area studied and an interaction between age and sex. Core range (50% KDE) were considered to investigate factors that affect their core ranging behaviour. Same factors used for the 95% KDE above were also included in the 50 KDE analysis. The continuous variables were standardised, selected models were checked for collinearity and dispersal, and residuals for normality and heteroskedasticity.

Generalized linear mixed models (R package lme4) were also used here to investigate what factors affected total prey returns, and for mammal, bird and reptile returns only. Site was included as a random factor. The independent variables included in the model were area of study, cat age (rounded to nearest year), distance from cat owner's home to conservation area, 95% KDE home range, although sex was not considered to influence prey return (Barratt, 1998) it was added to analysis to confirm findings in this study. An interaction between age and sex was also added. The continuous variables were standardised, selected models were checked for collinearity and dispersal, and residuals for normality and heteroskedasticity.

4.3 Result

At the beginning of the tracking, 53 cats were recruited for this study, although the number has reduced to 48 tracked cats as of March 2019. Thirty three (33) cats are in Ikota and 15 close to the conservation area with an average age of 2yrs. This reduction in cat number were primarily due to cat mortality, cats exhibiting signs of stress while wearing the tracker, change of owner's accommodation, and the killing of cats for meat. A tabulation of the areas and the cats involved for the tracking for both seasons with the KDEs values are captured in Table 4.2. Over the period inclusive of both the wet and dry season, home range sizes ranged from 0.07 ha to 10.443 ha at 95% KDE for all cats, with a mean home range size (95 % KDE) of 1.381 ha and maximum ranges size of 1.994 ha (98% KDE). The mean maximum area ranged was

2.347 ha (100% MCP), and this was recorded during the dry season and the absolute mean maximum daily area ranged by an individual cat in this study was 13.176 ha (100%MCP; Table 4.3A Appendix-1).

Table 4.2: The areas and the cats involved for the tracking for both seasons with calculated range sizes

Area	Cat	Sex	Age (yrs)	50% KDE ha	95% KDE ha	98% KDE ha	Area mean 98% KDE
Alphabeach	Milo	F	2.0	0.0867	0.8939	1.3821	
Alphabeach	Miss	F	1.0	0.0579	0.3215	0.4271	
Alphabeach	Pussycat	F	1.0	0.0437	0.4510	0.6570	0.8220
Barbwire	Bugatti	F	2.5	0.0414	0.3792	0.5795	
Barbwire	Tiger2	F	1.5	0.0321	0.3263	0.5157	
Barbwire	Followfollow	M	1.0	0.0600	0.4602	0.7384	
Barbwire	Lumen	M	1.5	0.4466	7.0028	10.2759	3.0274
ikota	Abiba	F	2.0	0.0850	0.5290	0.6844	
ikota	Arel	F	2.0	0.0372	0.5235	0.8405	
ikota	BigMummy	F	2.0	0.0918	0.6140	0.9013	
ikota	Cat	F	3.0	1.5408	7.3565	10.0217	
ikota	Cecilia	F	2.5	0.0938	0.7963	1.2168	
ikota	Comfort	F	2.0	0.2535	1.6478	2.3494	
ikota	Gifta	F	3.0	0.0943	0.6533	0.9179	
ikota	Gold	F	1.5	0.1224	1.1375	1.7097	
ikota	Joy	F	3.0	0.0870	0.6686	0.9414	
ikota	Katherine	F	2.0	0.1082	0.6088	1.0533	
ikota	Little	F	2.0	0.0209	0.2429	0.4703	
ikota	Mercy	F	3.0	0.0695	0.4941	0.6569	
ikota	Peace	F	2.0	0.0745	0.4639	0.6351	
ikota	Peace2	F	2.0	0.0469	0.4566	0.7031	
ikota	Pose	F	1.0	0.0613	0.3505	0.5220	
ikota	Queen	F	2.0	0.1329	1.1827	1.7318	
ikota	Ruth	F	3.0	0.0749	0.5702	0.9338	
ikota	Sandra	F	1.0	0.0960	0.5185	0.6544	
ikota	Seri-Mpanyi	F	2.5	0.0833	0.6910	1.1680	
ikota	Silver	F	2.0	0.0554	0.5256	0.7190	
ikota	Smallie	F	2.5	0.1651	0.9443	1.2843	
ikota	Tiger	F	2.0	0.1869	1.4005	2.0558	
ikota	Bogo	M	3.0	0.0980	0.5968	0.7969	
ikota	Bruce Lee	M	1.0	0.0507	0.3959	0.6808	
ikota	Cici	M	2.5	0.1118	0.8681	1.3840	
ikota	Holic	M	2.0	0.1177	0.6383	0.8569	
ikota	James	M	2.0	2.1962	10.0416	13.5150	
ikota	Lee	M	3.0	0.0696	0.4877	0.7130	
ikota	Macrom	M	2.0	0.0129	0.2410	0.4141	
ikota	Ransford	M	3.0	0.1422	0.7777	1.0183	

ikota	Success	M	1.5	0.0732	0.6882	1.0950	
ikota	Tom	M	3.0	0.0089	0.0674	0.0981	
ikota	VGC	M	1.5	0.2111	1.3922	2.1265	1.6627
owonikoko	Aisha	F	2.0	0.0683	0.5663	0.7746	
owonikoko	Bose2	F	2.0	0.0675	0.8721	1.3745	
owonikoko	Camfre	F	3.5	0.0989	0.9760	1.4181	
owonikoko	Catway	F	3.0	1.1243	10.4435	14.2424	
owonikoko	Finegirl	F	1.0	0.1682	2.0317	3.5799	
owonikoko	Minou	M	1.0	0.1162	1.0960	1.9559	
owonikoko	Shadow	M	2.5	0.0555	0.7693	1.2147	
owonikoko	Shine	M	2.0	0.0854	1.1008	1.6865	3.2808
		Mean	2.0833	0.1922	1.3805	1.9936	

Table 4.3: The most parsimonious models including significant independent variables for 95% (home) and 50% (core) KDE home ranges using generalized linear mixed models

Dependent variable	AIC		Intercept		Sex	Age		Location			Combination termsM2&3yrs
					M	2	3				
95% KDEs	105.04	Estimate coef	1.326				-0.995				(2.524)
		Standard error	0.344				0.391				(0.767)
		P-value	<0.001				0.014				(0.002)
		Model: 95 KDE.ha ~ age + sex + age: sex Family = inverse.gaussian (link = " inverse ")									

There were no significant differences in home range 95% KDE size between the study areas (χ^2 = 4.637, df = 3, P = 0.2; Table 4.3). Home range was largest at 50%, 95% and 98% KDEs for male cats as against the female cats (Table 4.2C; Appendix 4.1). For the difference in the home range size (95% KDE) between dry and wet season, the 95% KDE was significantly larger in the dry season (P = 0.05; 95% CI -0.0001 – 0.4286; median 0.2330) and for the difference in the home range size (50 and 95% KDE) between day and night, these were significantly larger in the night than in the day (P < 0.001; 95% CI -0.053 – -0.022; median =-(0.0376) P < 0.001; 95% CI -0.420 – -0.136; median = -0.244) respectively. For 50% KDE female one year old cats were significantly less likely to range beyond their 50 KDE core areas (P = 0.02).

For prey return, females and one year old cats in Alphabeach are significantly less likely to return prey per day, while male 2 and 3 year old cats are significantly more likely to return prey (P = 0.011 and P = 0.004

respectively; Table 3.3A, Appendix-1). Analysis shows female 1-year-old cats in Alphabeach are significantly less likely to return mammals ($P < 0.001$) and female 1-year-old cats in Ikota are more likely to return mammals ($P = 0.024$), as are 2 and 3-year-old male cats ($P = 0.025$ and $P = 0.014$ respectively). Cats in Alphabeach were significantly less likely to return birds ($P < 0.001$) and cats in Barbwire are significantly more likely to return birds ($P = 0.039$), while cats in Alphabeach were significantly less likely to return reptiles ($P < 0.001$; Table 4.3A, Appendix-1).

4.4 Discussion and Conclusion

The study objective for this chapter was to assess the core and home range size of pet domestic cats in a previously unstudied region, trying to understand how environmental features (season; time of day; access to prey; type of home) and individual features (cat age, sex, neuter status) affected each. To date there has been no similar study in Africa, with the exception of southern South Africa, and therefore this study greatly extends our global understanding of the behaviours of pet cats, as this is also the first study of its kind conducted in the tropics.

The sample sizes for our study compares favourably with the typical range of sample sizes for similar studies (Barratt 1997a; Meek 2003; Kays and DeWan 2004; Thomas et al. 2014; Pirie et al. 2022) and with a good mix of the sexes. It is noteworthy that less than 2% of the cats used in the study were neutered as against the norm in most other countries (Murray et al. 200; Thomas et al. 2012; Thomas et al. 2014; Pirie et al. 2022). Cat mortality recorded during the period of study were strikingly not of natural causes as the average age of the cats was just a little above 2 years which is less than the average age of cats recorded for studies in other countries. Many of the cats were reportedly killed for meat by some non-cat owners who lay traps for cats, while a few cat owners sell their cats for meat, particularly when the female cats has given birth and nurtured the kittens to a reasonable maturity stage where they can fend for themselves (Theresa Udofia, pers. obs.).

Ranging areas for this study are similar to results from other studies in other climates (Table 3.1), suggesting that while the home range size of the domestic cat may be limited by habitat availability (urban vs periurban cats; Pirie et al. 2022), when owned pet cats have freedom to roam then a typical home range is in the order of <1.5ha. As captured in most studies too, our study detected seasonal differences in the home range areas where we observed cats ranging further in the dry season possibly due to more favourable weather conditions (Barratt 1997a; Meek 2003; Morgan et al. 2009; Metsers et al. 2010; van Heezik et al. 2010), and some research suggests seeking mating opportunities decreases in the wet season/winter weather conditions (Brown 2006; Blottner et al. 2007; Kitts-Morgan et al 2015).

We examined how living next to purely conserved natural habitat, areas with more patches of green and garden type habitats can affects the home-range size and utilization. There were no significant differences in home range size between the four sections of the study area which were all typical mixed low to high density dwelling areas but numerically, Owonikoko and Barbwire recorded the largest home ranges in that order and these two are areas with more patches of green and garden type habitats with Barbwire directly bordering the Lekki conservation area. This suggest that cats resident in the immediate environs of the Lekki conservation area with its natural habitat, and areas with more patches of green and garden type habitats may integrate these areas into their home ranges (Thomas et al 2014).

The difference in the ranging areas between night and day was significant with cats seen to range further in the night than in the day and this outcome again is not dissimilar to the results of most other studies (Barratt 1997a; Metsers et al. 2010; Thomas et al 2014), though a few other studies have found no significant difference (Van Heezik et al. 2010). Where differences in home ranges between the night and day are absent, this may be ascribed to studies being of neutered suburban cats (Kitts-Morgan et al 2015). It has been argued that entire domestic cats ranging more widely in the night may be exhibiting the dominant ranging attitude of their wild ancestors, and feral cats are also noted to be more active at night (Alterio and Moller 1997; Thomas et al 2014).

Numerically the home range was largest for the male cats as against the female cats though not significantly difference. The non-significant outcome have been seen in some studies (Thomas et al. 2014), while the influence of sex, with males having larger ranges, have been regularly recorded in similar studies (Kays et al. 2020; Pirie et al. 2021), and also noted for feral cats in some studies (Guttilla et al. 2010; Gehrt et al 2013). The seasonal home range inclusive of both the wet and dry season from 0.07 ha to 10.40 ha at 95% KDE for all cats recorded in our study reflect findings of other research efforts and it is noted that home ranges of free-ranging cats varies extensively from 0.04-228 ha (Warner 1985; Barret 1997a; Weber & Dailly 1998; Horn et al. 2011; Thomas et al. 2014; Kitts-Morgan et al 2015; Kays et al. 2020; Pirie et al. 2022).

With the hunting behavior in cats, larger home ranges for cats brings danger to the environment as cats could potentially inflict more damage on wildlife. As a mitigation researchers have suggested buffer zone or outright banning of cat ownership around ecological zones of conservation interest (Leake and Cracknell 2006; Lilith et al. 2008; Thomas et al 2014; Pirie et al 2022) and Nigerians are significantly more positively disposed to accepting this measure as a possible means of containing cat predation (Chapter 2). In this study the absolute mean maximum daily area ranged by a cat was 13.18 ha, an equivalent of 230 m diameter for a circular area and a radius of 115m, with individual cats travelling much further. Outcomes from other research efforts using tracked cats have had maximum radii of >320m (Lilith et al. 2008;

Thomas et al. 2014) and with suggested buffer zone ranges of 300 meters being considered enough to reduce the entry of cats into areas of conservation concern. This study finds similar sized buffer zones are appropriate.

The role of cat traits in influencing predatory behaviour is considered in Chapter 5, as part of a larger study of prey returns. Here we wished to understand if roaming behaviour affecting prey return, and while prey returned by cats was affected by location, cat age and cat sex, no association was found between cat home range size and predatory behaviour.

In conclusion, it is important to understand how cats use their environment in considering issues of cat predation and mitigations and epidemiological investigations. Our study assessed the extent of the reach of free-ranging pet cats as they go about their daily activities and hunting of prey around the Lekki conservation area in Lagos, Nigeria, an area typical for the region of mixed low density to high density dwellings. Our study showed that seasonal differences exist in home range size, with cats ranging further in the dry season, ranging further at night and day, but no difference in range size as determined by cat sex. Cats with larger home ranges could potentially inflict more damage on wildlife and our study demonstrates buffer zones in the order of >300 meters would be effective in safeguarding important wildlife habitats in tropical habitats, just as much as in other parts of the world.

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4.6 Appendixes

Appendix 4.6.1: Tables

Table 4.3.1: Mean ranging area (95% Minimum convex polygon analysis (MCP) and maximum ranging area (MRA, 100% MCP) shown for studies of urban cat ranging behaviour and factors affecting their ranging behaviour. Where {m} means Male and {F} means Female.

Source of information	Study area	Duration of time used	Method Used	Proportion of cats	neutered	Sex	Mean RA 95% (Range)	Mean MRA (Range)	owned/unowned	Urbanization/Habitat	Day/Night	Season
Liberg, 1980	Southern Sweden	12 months	Radio-telemetry	55-72	NS	S			Both	N/A	Nill	NS
Barratt,1997	Canberra, Austrlia	9 months	Radio-telemetry	10	NS	NS	5.31(0.02-27.93)	8.58 (0.02-43.56)	Nill	S	S	NS
Meek, 2003	Bherwerre Peninsula, Australia	16 nights	Radio-telemetry	14	NS	NS	Nill	2.92 (0.04-14.65)	Both	Yes	Yes	Nill
Kays and De Wan, 2004	Albany, USA	4 month	Radio-telemetry	11		Nill	0.24 (0.0061-1.3)	0.65 (0.13-3.0)			Nill	Nill
Morgan et al.2009	Christchurch, New Zealand	12 months	Radio-telemetry	21	NS	NS	Nill	1.8 (0.1-10)			Nill	NS
Van Heezik et al.2010	Dunedin, New Zealand	6 days	GPS	32		NS	Nill	3.2 (0.48-21.5)			NS	Nill
Metsers et al. 2010	Canterbury, New Zealand	10 days	GPS	38			Nill	26 (3-72)				Nill

Guttilla and Stapp, 2010	Catalina, California, USA	29 months	Radio-telemetry	142	NS	Nill				Nill	Nill	NS
Horn et al.,2011	Urbana, Illinois, USA	15 months	Radio-telemetry	42	NS	NS	({m}1.83)&({F} 1.92		Both	Nill	Yes	Yes
Thomas et al. 2014	Reading, UK	2 months	GPS	20		NS	1.94(0.99-4.23)	6.88(1.69-11.15)	Both	Yes	S	NS
Hanmers et al. 2017	Reading, UK	months	GPS	38	NS	NS	1.28 (0.99-1.6)	<u>0.23 (50% KDE</u>)	Both	Yes	S	Yes
This study	Lagos, Nigeria	12months	GPS	48	No	NS	(1.38(95%KDE)	<u>3.28(KDE)</u>	Owned	Yes	Yes	Yes

Table 4.3.2A: The dry season mean 50% and 95% kernel density estimates (KDEs) and the mean ranging area, 50% and 95% Minimum convex polygon (MCPs) and 100% maximum ranging area (MCPs) for this study.

	Mean kernel density estimates (ha)		Mean ranging area (ha) MCP		Max ranging area
Cat name/month	50% KDEs	95% KDEs	50% MCPs	95% MCPs	100% MCPs
Arel_Dec	0.019	0.1	0.017	0.118	0.505
Arel_Feb	0.144	0.911	0.204	1.172	5.828
Arel_Jan	0.155	1.25	0.065	0.772	11.51
Arel_March	0.11	0.898	0.077	0.732	2.187
Bigmummy_Dec	0.06	0.256	0.105	0.251	0.306
Bigmummy_Feb	0.192	0.902	0.127	0.507	1.336
Bigmummy_March	0.053	0.419	0.026	0.226	1.698
Bogo_Feb	0.098	0.597	0.064	0.416	1.006
Bose1_Dec	0.105	0.695	0.057	0.397	1.494
Bruce Lee_March	0.061	0.661	0.033	0.503	3.545
Brucelee_Feb	0.047	0.3	0.037	0.248	0.89
Brucelee_Jan	0.065	0.374	0.052	0.254	1.08
Cat_Dec	1.544	7.351	1.014	5.95	13.072
Cecilia_Feb	0.089	0.751	0.062	0.626	1.925
Cecilia_Jan	0.046	0.212	0.032	0.132	0.184
Cecilia_March	0.249	1.643	0.219	1.195	1.823
Cici_Dec	0.127	0.869	0.087	0.592	2.205
Cici_Feb	0.097	0.699	0.077	0.557	1.5
Cici_Jan	0.217	1.462	0.117	0.917	1.61
Comfort_Feb	0.08	0.583	0.055	0.466	1.403
Comfort_Jan	0.065	0.395	0.037	0.257	1.202

Comfort_March	0.071	0.531	0.049	0.417	1.632
Gifta_Feb	0.118	1.004	0.039	0.619	1.112
Gold_Feb	0.273	2.187	0.288	3.696	4.704
Gold_March	0.172	0.673	0.065	0.275	0.326
Holic_Feb	0.114	0.592	0.089	0.393	0.815
James_Feb	0.159	1.063	0.097	0.639	1.846
James_Jan	0.039	0.242	0.029	0.181	0.627
James_March	0.037	0.389	0.019	0.303	5.246
Joy_Feb	0.052	0.271	0.023	0.104	0.239
Joy_Jan	0.288	1.495	0.064	0.446	4.162
Kathrine_Dec	0.01	0.079	0.014	0.089	0.735
Kathrine_Feb	3.741	20.775	0.822	8.619	10.974
Kathrine_March	0.079	0.531	0.044	0.381	0.779
Lee_Feb	0.071	0.466	0.047	0.255	0.68
Lee_March	0.109	0.652	0.072	0.358	0.718
Little_Dec	0.01	0.061	0.029	0.049	0.094
Little_Feb	0.046	0.443	0.027	0.328	1.024
Little_Jan	0.131	0.66	0.115	0.493	1.171
Little_March	0.149	1.041	0.097	0.86	1.275
Macrom_Dec	0.013	0.24	0.012	0.433	2.611
Mercy_Feb	0.07	0.494	0.047	0.374	1.082
Peace1_Jan	0.109	0.418	0.018	0.099	0.14
Peace2_Feb	0.041	0.326	0.029	0.258	1.13
Peace2_Jan	0.109	0.613	0.079	0.367	0.784
Peacecat_Feb	0.049	0.256	0.011	0.095	0.13
C4Peace_March	0.062	0.3	0.029	0.166	0.217
Peacecat2_March	0.047	0.409	0.034	0.335	1.326
Pose_Jan	0.054	0.317	0.034	0.2	0.919
Pose_March	0.064	0.353	0.046	0.247	0.671
Queen_Dec	0.022	0.481	0.013	0.699	0.973
Queen_Feb	0.074	0.528	0.049	0.377	1.175
Queen_March	0.046	0.363	0.016	0.14	0.41
Ruth_Feb	0.137	1.409	0.066	1.04	2.748
Ruth_Jan	0.115	0.705	0.048	0.337	5.542
Ruth_March	0.102	0.608	0.062	0.4	4.125
Seri-Mpanyi_Feb	0.136	1.214	0.073	1.146	2.636
Seri-mpanyi_March	0.087	0.833	0.028	0.502	1.821
Seri_mpani_Jan	0.079	0.526	0.043	0.336	1.13
Silver_Feb	0.108	0.717	0.072	0.583	1.16
Silver_March	0.064	0.437	0.035	0.273	0.47
Smallie_Feb	0.133	0.692	0.092	0.394	0.806
Smallie_March	0.131	0.913	0.094	0.687	1.472
Success_Dec	0.039	0.236	0.026	0.176	0.358
Success_Feb	0.06	0.458	0.042	0.347	1.875
Success_Jan	0.057	0.363	0.042	0.293	0.839
Success_March	0.23	1.71	0.193	1.702	2.875
Tiger_Feb	0.104	0.743	0.08	0.61	1.594
Tiger_Jan	0.083	0.431	0.056	0.301	0.485

Tiger_March	0.102	0.703	0.064	0.534	0.936
Tom_Dec	0.009	0.067	0.008	0.09	0.533
VGC_Feb	0.081	0.733	0.036	0.41	2.555
VGC_Jan	0.038	0.266	0.025	0.207	0.917
VGC_March	0.063	0.365	0.031	0.235	0.444
Aisha_Feb	0.078	0.602	0.044	0.456	1.045
Aisha_March	0.067	0.508	0.037	0.356	0.895
Bose_March	0.155	1.75	0.11	1.664	2.136
Bose2_Dec	0.078	1	0.042	1.003	1.416
Camfre_Feb	0.13	1.299	0.082	1.086	3.295
Catway_Dec	1.124	10.444	1.239	9.992	13.176
Finegirl_Dec	0.168	2.032	0.082	1.725	8.777
Minou_Jan	0.079	0.863	0.042	0.688	1.611
Minou_Dec	0.029	0.243	0.014	0.176	0.394
Minou_Feb	0.097	0.943	0.056	0.834	2.366
Minou_March	0.153	1.511	0.177	1.456	4.078
Papilo_March	0.08	0.376	0.044	0.22	0.273
Shadow_Dec	0.059	0.75	0.039	0.811	1.229
Shadow_Feb	0.052	0.223	0.03	0.106	0.146
Shadow_Jan	0.077	0.998	0.038	0.769	2.282
Shadow_March	0.145	1.1	0.089	0.742	1.613
Shine_Dec	0.085	1.101	0.042	0.853	3.085
Bugatti_March	0.073	0.535	0.093	0.426	3.623
Cinderella_Dec	0.113	1.435	0.041	1.114	1.856
Cinderella_Feb	0.043	0.302	0.013	0.15	0.24
Cinderella_March	0.042	0.449	0.012	0.307	0.592
Miss_Feb	0.046	0.207	0.007	0.049	0.079
Pussycat_Dec	0.016	0.095	0.013	0.099	0.171
Pussycat_Feb	0.105	0.542	0.074	0.435	0.642
Pussycat_Jan	0.203	1.504	0.098	0.863	7.562
Pussycat_March	0.199	1.27	0.044	0.314	1.737
Tiger2_March	0.077	0.476	0.19	0.504	1.47
Followfollow_Dec	0.036	0.224	0.031	0.21	1.091
jerry_BarbFeb	0.31	4.62	0.127	4.838	8.115
Jerry_Jan	0.165	2.836	0.069	3.37	7.403
Jerry_March	0.217	4.143	0.051	4.032	12.261
Lumen_Dec	0.153	1.193	0.064	0.621	3.569
Lumen_Feb	2.02	15.589	0.587	10.369	11.573
Mean	0.1727	1.2605	0.0930	0.9329	2.3473

Table 4.3.2B: Wet season mean ranging area, 50% and 95% Minimum convex polygon (MCPs) and 100% maximum ranging area (MCPs).

Cat name/season	WET_50 mcp ha	WET_95 mcp ha	WET_98 mcp ha	WET_100 mcp ha
Arel_wet	0.1089	0.7340	0.9821	1.6183
BigMummy_wet	0.1954	0.8726	1.1291	1.8153
Cecilia_wet	0.0802	0.5257	0.6833	0.8840
Comfort_wet	0.0712	1.4908	1.5329	1.6045
Ema_wet	0.0170	0.2463	0.3241	0.3400
Gifta_wet	0.0757	0.4950	0.7579	1.1313
Gold_wet	0.0810	0.8024	0.9858	3.5293
Holic_wet	0.0937	0.4612	0.6457	0.9132
Joy_wet	0.0564	0.5361	0.6657	0.9208
Lee_wet	0.0350	0.1649	0.1937	0.2678
Lucky_wet	0.0526	0.3295	0.5006	0.6706
Peace_wet	0.0592	0.4114	0.5409	0.7818
Pose_wet	0.0304	0.1583	0.1805	0.2438
Queen_wet	0.0469	0.5999	0.7622	1.1066
Ransford_wet	0.1093	0.6065	0.7684	1.0491
Ruth_wet	0.0510	0.3846	0.5227	0.8989
Sandra_wet	0.0680	0.3952	0.4969	0.5639
Seri-Mpanyi_wet	0.0510	0.2870	0.3305	0.6155
Silver_wet	0.0389	0.5200	0.5824	0.6443
Smallie_wet	0.1712	0.7498	0.8673	1.1337
Success_wet	0.0652	0.5587	0.7647	1.3779
Tiger_wet	0.2468	4.0071	4.0566	4.2403
VGC_wet	0.0269	0.3132	0.5203	0.9306
Aisha_wet	0.0061	0.0835	0.0984	0.1183
Bose2_wet	0.0387	0.3798	0.3798	1.2783
Camfre_wet	0.0639	0.7654	1.0566	1.2653
Leo_wet	0.0388	1.2378	1.4981	2.2974
Minou_wet	0.0231	0.2534	0.3781	1.4044
Shadow_wet	0.0405	0.5492	0.6675	1.1304
Spark_wet	0.0152	0.1877	0.3156	0.5371
Bugatti_wet	0.0255	0.2048	0.2980	0.5632
Miss_wet	0.0452	0.2749	0.3262	0.5097
Pussycat_wet	0.0935	0.4998	0.6412	1.6208
Tiger2_wet	0.0147	0.1189	0.2005	0.6759
Followfollow_wet	0.0681	0.5270	0.8497	1.6103
Mean	0.0659	0.5924	0.7287	1.1512

Table 4.3.2C: Gender mean core and home range values, 50% and 95% KDEs and maximum home range (98% KDE).

rea	cat in tracking	sex	age (yrs)	50 KDE ha	95 KDE ha	98 KDE ha
Alphabeach	Milo	F	2.0	0.0867	0.8939	1.3821
Alphabeach	Miss	F	1.0	0.0579	0.3215	0.4271
Alphabeach	Pussycat	F	1.0	0.0437	0.4510	0.6570
Barbwire	Bugatti	F	2.5	0.0414	0.3792	0.5795
Barbwire	Tiger2	F	1.5	0.0321	0.3263	0.5157
ikota	Abiba	F	2.0	0.0850	0.5290	0.6844
ikota	Arel	F	2.0	0.0372	0.5235	0.8405
ikota	BigMummy	F	2.0	0.0918	0.6140	0.9013
ikota	Cat	F	3.0	1.5408	7.3565	10.0217
ikota	Cecilia	F	2.5	0.0938	0.7963	1.2168
ikota	Comfort	F	2.0	0.2535	1.6478	2.3494
ikota	Gifta	F	3.0	0.0943	0.6533	0.9179
ikota	Gold	F	1.5	0.1224	1.1375	1.7097
ikota	Joy	F	3.0	0.0870	0.6686	0.9414
ikota	Katherine	F	2.0	0.1082	0.6088	1.0533
ikota	Little	F	2.0	0.0209	0.2429	0.4703
ikota	Mercy	F	3.0	0.0695	0.4941	0.6569
ikota	Peace	F	2.0	0.0745	0.4639	0.6351
ikota	Peace2	F	2.0	0.0469	0.4566	0.7031
ikota	Pose	F	1.0	0.0613	0.3505	0.5220
ikota	Queen	F	2.0	0.1329	1.1827	1.7318
ikota	Ruth	F	3.0	0.0749	0.5702	0.9338
ikota	Sandra	F	1.0	0.0960	0.5185	0.6544
ikota	Seri-Mpanyi	F	2.5	0.0833	0.6910	1.1680
ikota	Silver	F	2.0	0.0554	0.5256	0.7190
ikota	Smallie	F	2.5	0.1651	0.9443	1.2843
ikota	Tiger	F	2.0	0.1869	1.4005	2.0558
owonikoko	Aisha	F	2.0	0.0683	0.5663	0.7746
owonikoko	Bose2	F	2.0	0.0675	0.8721	1.3745
owonikoko	Camfre	F	3.5	0.0989	0.9760	1.4181
owonikoko	Catway	F	3.0	1.1243	10.4435	14.2424
owonikoko	Finegirl	F	1.0	0.1682	2.0317	3.5799
				0.1678	**1.2387**	**1.7850**
Barbwire	Followfollow	M	1.0	0.0600	0.4602	0.7384
Barbwire	Lumen	M	1.5	0.4466	7.0028	10.2759
ikota	Bogo	M	3.0	0.0980	0.5968	0.7969
ikota	Bruce Lee	M	1.0	0.0507	0.3959	0.6808
ikota	Cici	M	2.5	0.1118	0.8681	1.3840
ikota	Holic	M	2.0	0.1177	0.6383	0.8569

ikota	James	M	2.0	2.1962	10.0416	13.5150
ikota	Lee	M	3.0	0.0696	0.4877	0.7130
ikota	Macrom	M	2.0	0.0129	0.2410	0.4141
ikota	Ransford	M	3.0	0.1422	0.7777	1.0183
ikota	Success	M	1.5	0.0732	0.6882	1.0950
ikota	Tom	M	3.0	0.0089	0.0674	0.0981
ikota	VGC	M	1.5	0.2111	1.3922	2.1265
owonikoko	Minou	M	1.0	0.1162	1.0960	1.9559
owonikoko	Shadow	M	2.5	0.0555	0.7693	1.2147
owonikoko	Shine	M	2.0	0.0854	1.1008	1.6865
		Mean	**2.0313**	**0.2410**	**1.6640**	**2.4106**

Table 4.3.3A Appendix -1: The most parsimonious models for Mean daily prey returned per cat and mammals, birds and reptiles only using General linear model.

Dependent variable	AIC		(Intercept)	Distance to lekki cons.	Sex	Age		Location			Combination terms 2yrs.M (3yrs.M)
					M	2	3	Barb wire	Ikota	Owonikoko	
Mean daily prey return per cat	-188.91	Estimate coef	**-1.029**						**-0.126**		**0.190 (0.259)**
		Standard error	**0.058**						**0.065**		**0.072 (0.085)**
		P-value	**<0.001**						**0.058**		**0.011 (0.004)**
		Model used : Mean daily prey return per cat ~ area used for home range + age + sex + distance .lekki conservation . + X95KDE + area.for_home.range: age area.for_home.range: sex + area.for_home.range:distance_to.lekki. + age: sex									
		Family: gaussian(link = "log")									

Mammal returned	-233.26	Estimate coef	– 2.328						0.351		0.338 (0.404)
		Standard error	0.139						0.150		0.145 (0.158)
		P-value	<0.001						0.024		0.025 (0.014)
		Global model used : mammal perday ~ area.for_home.range + sex + age + X95.KDE.ha + distance to leki									
		Family: gaussian(link = "log")									
Birds	8.8935	Estimate coef	-2.406						0.387		
		Standard error	0.144						0.182		
		P-value	<0.001						0.039		
		Global model used: Bird ~ area.for_home range + sex + age + X95.KDE.ha + distance to leki + age:sex									
		Family: gaussian(link = "identity")									
Reptiles		Estimate coef	-2.567								
		Standard error	0.174								
		P-value	<0.001								
		Global model used: Reptile ~ area.for_home.range + sex + age + X95.KDE.ha + distance to leki. + age:sex									
		Family: gaussian(link = "identity")									

Chapter 5.0

Estimation of predation rates by pet cats in Lagos, Nigeria.

5.1 Abstract

The Domestic cat Felis catus is a global species and are associated with species extinction in some ecosystems as they are efficient hunters and pose a great threat to biodiversity largely through direct predation. Our study is the first to consider cat predation in the continent of Africa outside of South Africa and is one of the few in the tropics or sub-tropics.

We examined predation by urban domestic cats in the megacity of Lagos, Nigeria with a total of 103 cats were recruited across all locations over the 19, whereby cat owners were asked to record live and dead prey returned home by their cat over the period. We found that individual cats varied in the volume of prey returned, with mean daily return rates ranging from 0.1 to 0.64 prey. Mammals and birds were the predominant prey groups (31.3% and 26.6% of prey respectively), with rodents being the predominant (84.7%) mammal prey.

Predation rates were higher in dry seasons, with the mean daily predation rates for the dry and wet seasons being 1.32 and 1.05 respectively. The mean annual predation rate of 412 prey per cat per year is high compared to previous studies, which typically range from 14 to 302 prey per cat per year depending on location. The sex of the cat did significantly affect the total mean daily rate of prey return as male cats were significantly more likely to return prey compared to females. For the main taxa this was skewed by age as male cats with age 2 and 3 year old cats were significantly more likely to return mammals compared to females of the same age.

Our study found that cats carrying GPS trackers, for both dry and wet seasons, were significantly less likely to return prey than cats that were not tracked and presupposed that situations where cats are wearing collars or anti-predation devices would have significantly reduced predation rates and this the position is collaborated by recent studies UK.

Our Study show that rates of predation by pet cats in urban Lagos are substantial, with perhaps in the region of 100 million vertebrates killed by owned cats in the city alone and likely to be a significant cause of mortality of small and mid-sized terrestrial vertebrates in west Africa.

5.2 Introduction

The Domestic cat *Felis catus* is a global species, having been introduced by people to most parts of the world, particularly in recent centuries, where they have been introduced to parts of North and South America, Australia and to Pacific islands (Lowe et al. 2000; Woods et al. 2003; Driscoll et al. 2007). Cats are carnivores associated with species extinction in some ecosystems (Kirkpatrick and Rauzon, 1986; Fitzgerald and Turner, 2000; Butchart et al. 2006; Baker et al. 2008, Medina et al. 2011; Doherty et al.

2016), as they are efficient hunters (Loyd et al. 2013; Dickman and Newsome, 2015; Hanmer et al. 2017) and pose a great threat to biodiversity (Barratt, 1997b, 1998; Wood et al. 2003; Baker et al. 2005; Van Heezik et al. 2010; Medina et al. 2011; Thomas et al. 2012; Kitts-Morgan et al. 2015; Doherty et al. 2016 Hanmer et al. 2017), largely through direct predation (George et al. 2010; Bellard et al. 2016).

Cats are often grouped into three main categories depending on their relationship with humans, where and how they live. ‘Pet cats’ are cats living in close association with a household and all its needs are catered for by its owner (Moodie, 1995; Dickman, 1996; Brickner 2003; George 2010). Cats designated as ‘stray cats’ are free roaming cats not owned by anyone and they rely partly on human provision for survival, while free roaming cats not relying on humans for support are designated as ‘feral cats’ (Moodie, 1995). However, most literature uses the term feral cats to collectively represent both stray and feral cats (George 2010). The annual mortality of fauna credited by feral and domestic cat predation is estimated to be in the millions globally (Churcher and Lawton, 1987; Robertson 1998; Hawkins et al. 2004; Dauphine and Cooper, 2009; Denny and Dickman, 2010; Loss et al. 2012; Loyd et al. 2013, Dickman and Newsome 2015; Pirie et al. 2022).

Cats kills large number of prey; they are the primary threat to over 8% of threatened reptiles, birds, and mammals (Medina et al. 2011; Doherty et al. 2016). They have been linked with 26% of the total extinctions of reptiles, birds, and mammals in the world since 1600 (Doherty et al. 2016) and approximately 33% of all known extinctions on the islands are thought to be the result of predation by cats (Lever, 1994). The impact of cats on native fauna is the greatest on islands, where native fauna had originally evolved without exposure to cats or similar carnivores (Campbell et al. 2011; Medina et al. 2011; Nogales et al. 2013). In Australia, cat predation is the cause of the decline or extinction of two thirds of Australia’s digging mammal species (Fleming et al. 2014) and are causing the decline in populations of at least 123 other threatened native species (Legge et al. 2020). Cat predation on mainland areas has also been considered problematic for biodiversity because of their high population densities (Woods et al. 2003; Sims et al. 2008; Hanmer et al. 2017).

Cats are present at high densities on the mainland, particularly urban areas, because cat populations are associated with humans (Sims et al. 2008). In some urban areas the population density of cats can be exceptionally high with figures reaching ~200–2000 cat’s km^{-2} (Liberg et al. 2000; Sims et al. 2008; Baker et al. 2010; Thomas et al. 2012). Studies have shown that domestic cats are the most abundant predator in many urban ecosystems (Liberg et al. 2000; Loss et al. 2013; Thomas et al. 2012; Hanmer et al. 2017) and with growing urbanization, cat predation has the potential to overwhelm the carrying capacity of their ecosystem as cat populations increase (Beckerman et al. 2007; Thomas et al. 2012; Seymour et al. 2020). Studies show prey type and opportunities differ extensively with geographical and ecological regions

(Kitts-Morgan et al. 2015; Pirie et al. 2022), however direct predation is not the only means by which domestic cats reduce prey populations. Risk aversion and other fear effects created merely by cat presence negatively affects prey behaviour, habitat utilization (Lima, 1987; Beckerman et al. 2007) and changes prey foraging habits, thus influencing their survival rates (Bonnington et al. 2013).

The composition of different prey types from major studies around the world include six different studies in the UK (Churcher, 1987; Carss, 1995; Woods, 2003; Baker, 2008; Thomas et al. 2012; McDonald et al. 2015; Pirie et al. 2022), Australia (Barratt, 1997) and New Zealand (Hansen, 2010) which indicates prey is comprised of ~50-70 % mammals, ~22-30 % birds and ~8–20% for herptiles (Table 5.1). In California, Hawkins et al. (2004) found that cat predation was responsible for the population reduction of native rodents and birds in the vicinity of a cat feeding area and a more recent study estimates mortality caused by free-ranging domestic cats in the United States in the range of 1.3–4.0 billion birds and 6.3–22.3 billion mammals annually (Loss et al. 2012). Mortality estimates for birds in Canada ranges between 100 and 350 million (Blancher, 2013) and in South Africa, estimates of 216 million prey are killed per year by an estimated 2.4 million domestic cats (Seymour et al. 2020). Based on extrapolations Woods et al. (2003) suggested that the estimated 9 million cats in UK were involved in killing approximately 85-100 million prey items comprising of 52-63 million mammals, 25-29 million birds and 4-6 million reptiles and amphibians per annum, while Pirie et al. (2022) suggest larger numbers, totalling over 220 million prey per year in Britain. An earlier study noted that a third of the house sparrows in a village in Oxfordshire, UK were killed by cats (Churcher and Lawton, (1987). Although prey return rates are highly variable across the seasons, a study in the UK found a mean predation rate of 18.3 prey cat^{-1} $year^{-1}$ (Thomas et al. 2012).

Table-5.1: The proportion of different prey types recorded in twelve studies. The percentage of each prey type of the total for each study is given in parenthesis. (After Baker et al 2010 and Thomas et al. 2012).

Source	Location	Mammals	Birds	herpetofauna/Fish	Inverts	Unknown
Churcher (1987)	UK	535 (49)	297 (27)			258 (4)
Carss (1995)	Scotland	195 (95)	11 (5)			
Barratt (1997)	Australia	1273 (65)	529 (27)	157 (8)		2 (0)
Gillies and Clout 2002	New Zealand	520	226	47	787	
Woods (2003)	UK	9852 (69)	3391 (24)	1355 (9)	305 (2)	191 (1)
Baker(2008)	UK	269 (75)	86 (24)	3 (1)		
Hansen(2010)	New Zealand	253 (86)	37 (13)	3 (1)	3 (1)	
Thomas et al (2012)	UK	748 (65)	345 (30)	58 (5)		
McDonald et al (2015)	UK	190 (59)	86 (27)	28 (9)		20 (6)
Krauze-Gryz et al. 2018	Poland	216	49	-	-	-
Méndez et al 2022	Mexico	19(7.7)	38(15.4)	132(53.7)	57(23.2)	
Pirie et al. 2022	UK	311(69)	110(25)	20(3)	6(1)	33

Due to the experimental complications associated with other approaches to carrying out predation studies (Thomas et al. 2012) and challenges of using cat-borne cameras, most cat predation studies adopt the prey return approach to obtaining predation rates. Prey return programmes carried out for a sufficient length of time to account for intra-annual variation in predator-prey systems, prey abundance and cat behaviours are advised. Few data exist on how predation patterns vary between the seasons in a year and spatially within an urban setting (Baker et al. 2008; Van-Heezik et al. 2010; Thomas et al. 2012; Pirie et al. 2022).

Converting prey return data to applicable predation rates is more complex due to uncertainties in accounting for prey killed and not returned home and the survival rates of those released alive during survival struggle of prey (Maclean, 2007; Thomas et al. 2012). Table 5.2 provides a summary of predation studies of urban cat populations (after Baker et al 2010 and Thomas *et al.* 2012). The majority of cat predation studies took place in Australia (Barratt, 1997, 1998; Frank et al. 2014; McGregor et al. 2015; Woinarski et al. 2018); the UK (e.g., Baker et al. 2005, 2008; Thomas et al. 2012; McDonald et al. 2015; Pirie et al. 2022); Canada (Blancher, 2013; Flockhart et al. 2016), Europe (Krauze-Gryz et al. 2012; Mori et al. 2019; Tschanz et al. 2011); New Zealand (Gillies and Clout, 2003; van Heezik et al. 2010; Scrimgeour et al. 2012); and the USA (Lepczyk et al. 2004; Loss et al. 2013; Loyd et al. 2013).

Studies are therefore from a limited number of countries, so while we can extrapolate from these, an inherent risk exists as these studies took place at sites with ecological backgrounds differing from much of the world (Seymour at al. 2020). To date there have been no studies in the biodiverse tropics, such as in Africa outside of South Africa (Morlings, 2014; Seymour et al. 2020), yet Africa and the tropics are massively important for biodiversity (UNEP-WCMC, 2016). Nigeria therefore presents a tropical ecosystem different from South Africa and the Western nations that studies have been done. In our recent study on people's attitude towards cats (Chapter 2) it was indicated that the major reason for people keeping cats in Nigeria is for pest control and this might likely be the case across West Africa with shared customs and ways of life. This is unlike Western countries where people mostly keep cats for companionship (Driscoll et al. 2009; Murray et al. 2010; Blancher, 2013; Aeger et al. 2017; Chapter 6).

Though cats kill many prey, explicit confirmation of a negative effect on prey populations in regions where cats have been present for centuries is yet to be ascertained as there is scientific uncertainty regarding the degree to which cats threaten native wildlife populations (Lilith et al. 2006) and further studies are needed. This study is the first to ask what cats are killing and their predation rate is in Lagos, Nigeria (Faria, 2021). We compare differences in the rate and diversity of prey return by cats in four areas; two heavily urbanised and two near the Lekki conservation centre; a relatively large (78 hectares; Talabi, 2016)

Table 5.2. Summary of study details, predation rates and prey composition recorded in studies of urban cat populations. Modified from Baker et al. 2010 and Thomas et al. 2012.

Location	Habitat	Study type^2	Cat density(km^2)	No. of cats studied	Length of study	Return rate^4	Annual predation rate^5	Mammals	Birds (%)	Herptiles (%)	Other (%)	Source
Canberra	Urban	A	-	214	1 year	9.2 year^-1	30	68	25	7	-	Barratt(1997, 1998)
California, USA	Chaparral	Unknown	-	Unknown	Unknown	36 year^-1	185	43	27	30	-	Crooks & Soule (1999)^8
Lancashire, UK	Various	B	-	41	8 weeks	5.5 month^-1	218	69	22	8	-	Ruxton *et al*. (2002)
Auckland, NZ	Urban	A	-	46	1 year	20.4 year^-1	67	5	14	5	76	Gillies & Clout (2003)
Auckland, NZ	Urban fringe	A	-	34	1 year	21.6 year^-1	71	67	14	10	10	Gillies & Clout (2003)
UK	Various	A	-	986	5 months	2.9 month^-1	115	69	24	5	2	Woods et *al.* (2003)
Michigan, USA	Urban	C	343	106	5 months	0.77^7 week^-1	120	-	(100	-	-	Lepczyk et al. (2004)
Albany, USA	Urban nr NR^1	B	32^6	12	3 months	1.67 month^-1	66	86	14	-	-	Kays & DeWan (2004)
Michigan, USA	Suburban	C	137	72	5 months	0.58^7 week 1	100	-	(100	-	-	Lepczyk *et al*. (2004)
Bristol, UK	Urban	A	229	131	1 year	6.5 year^-1	21	72	28	<1	-	Baker *et al*. (2005)
UK	Various	B	-	89	3 months	3.5 month^-1	138	59	38	-	4	Nelson *et al*. (2005)
Perth, Australia	Urban	B	-	56	6 weeks	1.76 week^-1	302	55	22	23	-	Calver *et al*. (2007)
Bristol, UK	Urban	A	290-420	275	1 year	4.3 year^-1	14	66	24	9	<1	Baker *et al.* (2008)^5
Christchurch, NZ	Urban nr NR^1	A	252	88	1 year	11.5 year^-1	37	38	20	19	22	Morgan *et al*. (2009)
NZ	Various	B	-	37	12 weeks	0.86 week^-1	148	59	33	3	5	Gordon *et al*. (2010)
Dunedin, NZ	Urban	A	233	144	1 year	13.4 year^-1	43	35	37	8	20	van Heezik *et al*. (2010)
Reading, Uk	Urban	A	248 -445			18.3 year^-1						Thomas et al. (2012)
Poland	Urban/Rural	A		26	5 years	8.89		50	36.5		13.5	Krauze-Gryz et al 2017
Berkshire & Ha	Urban	A	-	79	1 year	5.2		69	25	4	-	Pirie et al. (2022)

biodiverse protected area in the heart of Lekki-Lagos. This would reveal the possible prey species cats may be affecting around the Lekki conservation centre and between the low-density and high-density residential areas in this study. The study area also presents an extensive habitat for possible prey like mammals, invertebrates, herpetofauna/fish, and birds. We asked volunteers to collect prey and used the collated data to investigate 1) What type of prey are returned; 2) What factors influence prey return; and 3) if the rate of prey returned by cats differed between the dry and wet seasons.

5.3 Methods

5.3.1. Study site

This study was carried out in Lekki, Lagos, Nigeria, Africa (6°27′ 14.65″ N, 3°23′ 40.81″ E) from November 2018 – June 2020. Greater Lagos is the most densely populated city in Nigeria with mostly mixed density residential areas, with an estimated population of 21m people dwelling in a total city coverage area of 1,171 km² (Rosenthal 2012; City Population, 2015). There are two seasons in Lagos; a wet season which lasts from April to October, and a dry season lasting from November to March.

The study was conducted in four arears in the Eti Osa Local Government Area: the urban residential areas of cum conservation catchment of Alpha–Beach, Barbwire, Owonikoko and of these study areas are mixed residential development urban settings with presence of wetland and woodland with Barbwire having in addition small water bodies running through part of it. Ikota study area (termed urban), is 4.0 kilometres away from Lekki conservation centre (measured from the middle of the sites), while Barbwire, Alpha-Beach and Owonikoko (termed conservation catchment), share boundaries with the Lekki conservation centre. The Lekki conservation centre is a large biodiversity conservation and environmental educational park in the centre of the Lekki peninsula, which covers an area of 78 hectares (Talabi, 2016) and is of considerable conservation value. It spans a montage of vegetation types: secondary forest, swamp forest and Savanna grassland. The conservation centre is home to a diverse species of plant and animals. Some of the animals that have been identified in the conservation area includes bushbuck, Maxwell's duiker, African civet (Civettictis civetta), African giant rat(*Cricetomys emini*) hogs, mongoose, squirrels), mona monkey (*Cercopithecus mona*), and an impressive variety of birdlife like the Black Kite (Milvus migrans), Grey Kestrel (*Falco ardosiaceus*), Red-eared dove (*Streptopelia semitorquata*), Blue spotted wood-dove (*Turtur afer*), Piping hornbill (*Bycanistes fistulator*), Common bulbul (*Pyanonotus barbatus*),

and reptiles including crocodiles (*Crocodylus suchus*), alligator lizards (*Elgaria* species), chameleons (*Chamaeleo africanus*), monitor lizards (*Varanus* species), and many species of snake amongst others (GogeAfricaTV 2015; Stephen 2000, Van der Straeten and Peterhans 2004.).

Figure 5.1: Study sites for cat predation study in Lekki Lagos, Nigeria (map produced from 2021 Google Earth satellite image).

5.3.2 Recruitment of cats.

Door-to-door recruitment of cat owners was done to facilitate cat owner's engagement with the study. Cats were recruited from houses within both study areas (conservation and urban areas). Households who owned cats were asked information about the cat's sex, age, whether they feed their cat, if the cat had free access to the outside, if they were neutered or not, and if their cat wore an anti-predation device. Only cats which were given free access to the outside and beyond their owner's houses were enrolled in the study.

5.3.3 Cat prey returns collection.

A total of 103 cats were recruited across all locations over the 19 months with 84 cats recruited at the beginning and 19 cats later joined in 2020. Fifty six of these cats were also part of the cat ranging study (Chapter 2) which allowed us to investigate if cat tracking affected prey return. Cat numbers participating reduced from the initial 84 cats going into 2020 largely due to cat mortality (often through the killing of cats for meat), cats exhibiting signs of stress while wearing the tracker, or a change of owner's accommodation.

Cat owners in the study were asked to record live and dead prey returned home by their cat. Where possible, the cat owners were asked to take pictures of the prey and record the date the cat brought the prey back, the type of prey returned (categorised as birds, small mammals, large mammals, reptiles, amphibians, insects, mollusc, and known common names). In addition, owners were asked to save any dead prey items that were returned in a freezer until the specimens could be collected by the researcher. For statistical analyses, only households with a single cat were used to avoid problems encountered by households with multiple cats, where distinguishing which prey was returned by each cat would be very difficult. Prey returned alive was included as part of the mortality estimates as guided by general believe that live prey return by cats seldom survive (Smit et al. 1980; Thomas et al. 2012).

5.3.4 Return rates and predation rate analysis

The first dry season records started from December 2018 to March 2019 (4 months) and the second dry season had the full five months spread from November 2019 to March 2020. Records for the first wet season spanned April –October 2019 (7 months) but the second wet season started in April 2020 and truncated after 3 months in June 2020 due to COVID-19 restrictions. To account for a difference in season lengths and variation in cat participation throughout the period daily mean prey return rates were calculated to compare like with like. Mean total daily prey return rates were calculated as the sum of total prey returned by a cat throughout the duration the cat was in the study, divided by the number of days the cat was in the study. A mean daily return rate was also calculated for the dry and wet seasons and for each taxa.

Total predation rates were calculated from the prey return rates using a conversion factor relating to the proportion of prey killed that were not returned home. From other predation studies the percentage of prey that was returned home used factor ranges from 50% (George, 1974), or 30% (Kays and DeWan, 2004; Thomas et al. 2012) to 12.5% (Maclean, 2007). This wide range reflects the subjectivity of the conversion factor to individual study peculiarities. Also result of studies reassessing predation through kitty cams (collar mounted cameras) have found values of 23% (Loyd et al 2013), 22% (Morling 2014) and 18% (Seymour et al 2020), for percentage of prey that is returned home. Given the lack of information on return rates in areas such as this, we have taken a conservative approach and adopted the highest percentage quoted for prey return home from a radio-tracked cats' direct observation and collar mounted cameras sources which is 30% and hence overall mortality is estimated using a 3.3 prey return conversion factor (Kays and DeWan, 2004). For this analysis we have grouped prey at low taxonomic resolution as the lack of refrigeration facilities in many homes meant that we relied upon photographs taken by our volunteers for many samples.

Statistical analyses were carried out in R statistical Software (R Core Team 2018, version 3.5.1). Data were normal so general linear models with gaussian error family and log link function were used to determine what factors (age, sex, area, if the cat was in the tracking study, and the interactions between area and age, area and sex, area and cat in tracking study, age and sex) affected the mean total daily prey returned by cats over the year and for each season separately. To obtain the minimum acceptable model (Crawley 2010), a backward sequential deletion was applied to the global model.

To investigate what factors affected the mean total daily mammal, bird and reptile returns by cats over the year, data were log transformed then general linear models with gaussian error family and identity link function were used. The same factors were included in the global model as stated previously, using the backward sequential deletion to determine the final models.

Wilcoxon signed rank tests were used to check for a difference in the mean daily return rate of mammals, birds and reptile per day per cat between the dry and wet seasons as data were not normally distributed. Mean daily return rates for each taxon per area were then compared using Wilcoxon signed rank test for mammals as data were not normally distributed and paired t-tests for birds and reptiles.

5.4 Result

Prey return data were collected from 103 families who own cats of which 84 cats started from the beginning for the data collection and 19 cats participated in the study between January 2020 and June 2020. Sixteen cats dropped out at the end of 2019 from the original starter group of 84 cats, which left 68 cats participating in data collection throughout the study period (Table 5.3).

Table 5.3: Numbers of participating cats per area

Area	Cats per Area	cats lost 2019	Cats added in 2020	Total
Alphabeach	21	5		21
Barbwire	9		1	10
Ikota	46	10	10	56
Owonikoko	8	1	8	16
Grand total	84	16	19	103

A total of 17,202 prey was recorded across all locations over the 19 months with a mean daily prey return rate of 0.36 (±SE 0.006) and mean monthly return rate of 10.75 (±SE 0.285). Ikota had the highest number of cats (table 3) with a prey return of 8838 (51.4%), followed by Alpha-beach with 4282 (24.9%), Owonikoko with 2187 (12.7%) and Barbwire 1895 (11.0%; Table 4). When mean daily prey return rate per day was considered for the four areas, Alpha-beach had the highest value (11.69 ±SE 0.375), followed by Owonikoko (11.03 ±SE 0.511), Barbwire (10.46 ±SE 0.584), and lastly Ikota (10.28 ±SE 0.436).

Table 5.4: Count of prey type per area of study and Count of prey per cat per month per area of study

	Count of prey type				**Prey per cat per month**			
Prey type	**Alpha beach**	**Barbwire**	**Ikota**	**Owonikoko**	**Alpha beach**	**Barbwire**	**Ikota**	**Owonikoko**
amphibian	364	181	707	296	1	1	0.82	1.53
bird	1350	684	1931	595	3.7	3.78	2.25	3.07
crustacean	183	38	164	83	0.5	0.21	0.19	0.43
egg	2	3	1	2	0.01	0.02	0	0.01
insect	314	117	777	147	0.86	0.65	0.91	0.76
mammal	1066	486	3251	574	2.92	2.69	3.79	2.96
mollusc	125	36	188	30	0.34	0.2	0.22	0.15

reptile	856	326	1557	443		2.35	1.8	1.81	2.28
unknown	5	6	208	5		0.01	0.03	0.24	0.03
worm	17	18	54	12		0.05	0.1	0.06	0.06
total	**4282**	**1895**	**8838**	**2187**		**11.74**	**10.48**	**10.29**	**11.28**
percentage	**24.89**	**11.02**	**51.38**	**12.71**					

Of the total prey return (N = 17202) across all four locations mammals were the most recorded prey captured with 5377 returns. Birds were the second most recorded prey returned accounting for 4568 of all recorded entries. Reptiles accounted for 3182 of all recorded prey returned, followed by amphibians 1543, and invertebrates (insects 1355, crustaceans 468, mollusc 384 and worms 101; with 224 unknown prey returned. Figure 4.2 captures the composition of prey returned by cats in this study. Mammals were predominantly rodents (84.7%); with rat (34.4%), squirrel (17.8%), mouse (14.2%), and dormouse (10.3%) accounting for the majority of the rodents. The birds included species were barn swallow, blackbird, bulbul, crow, duck pigeon, sunbird, starling and wagtails

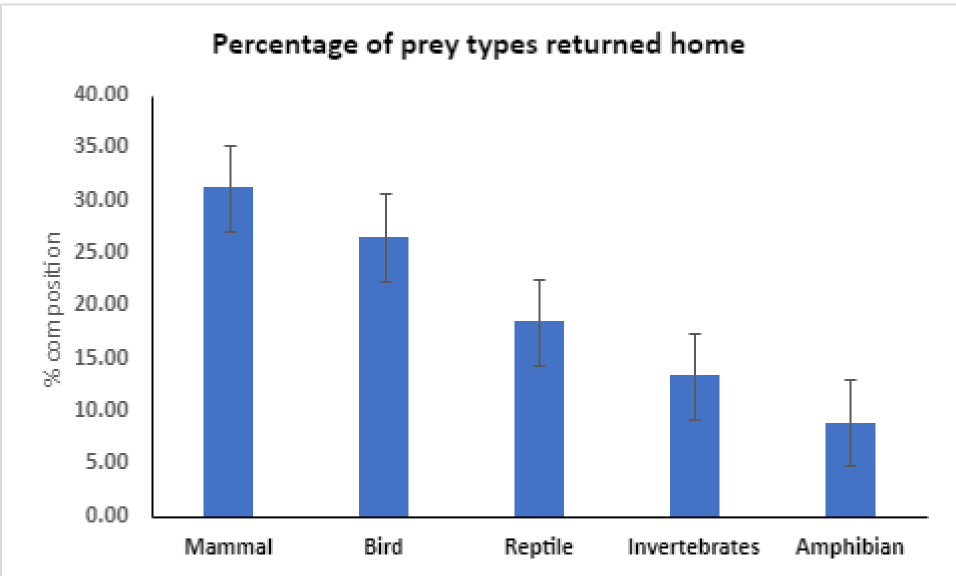

Figure 5.2: Percentage of prey types returned home by cats in Lagos, Nigeria

The mean daily return rate for each of the dry and wet seasons were 0.38 for the first dry season period December 2018 to March 2019 (four months) and 0.31 for the first full wet season April –October 2019 (seven months), 0.42 for the second full dry season of five months spread from November 2019 to March 2020 and 0.33 for the second wet season April to June 2020. The mean return rates for the seasons calculated are (0.40±0.034; mean±SE) for the dry season and (0.32±0.038) for the wet season. The corresponding predation rates for each of the dry and each of the wet seasons are 1.25, 1.02, 1.39 and 1.09 respectively for the first dry season period, the first wet season, the second dry season and the second wet season. Figure 5.3 shows the mean predation rates for the seasons calculated for the dry season (1.32) and for the wet season (1.05). The annual return rate of prey per cat per year calculated from 2019 data gives 124.94 prey per cat per year and the corresponding annual predation rate as 412.45 prey per cat per year.

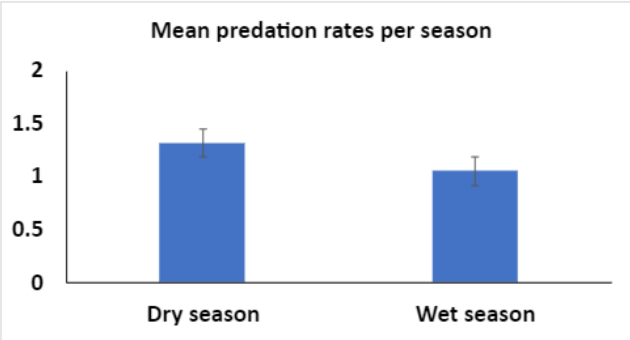

Figure 5.3 Mean predation rates per season

Factors affecting mean daily prey returns per cat for the year and seasons

The sex of the cat did significantly affect the total mean daily rate of prey return as male cats were significantly more likely to return prey compared to females (Table 5.5). In addition cats from Ikota had a significantly lower mean total daily prey return per cat compared to Alpha-beach, but Owonikoko and Barb wire locations were not significantly different (Table 5.5).

The numbers of prey brought home were affected by the season as more prey were brought home by cats during the dry season than the wet season (Figure. 5.3). For both the dry and wet seasons male cats were significantly more likely to return prey compared to females (Table 5.5), with cats from Ikota significantly returning less in both seasons (Figure 5.4) and cats in Barbwire significantly returning fewer prey in the wet season compared to cats in Alpha-beach. In the wet season cats that were tracked were significantly less likely to return prey than cats that were not tracked.

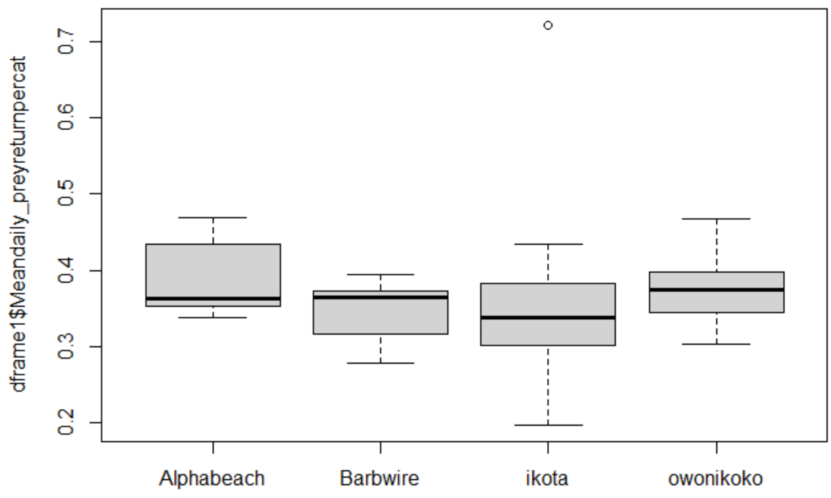

Figure 5.4. Mean prey return per day by cats according to location.

Table 5.5: Final general linear models for mean total daily prey return for the year and for both dry and wet seasons.

	AIC		(Intercept)	Cat tracking	Sex	Age		Location			Combination terms
				Yes	M	2	3	Barbwire	Ikota	Owonikoko	
a. Mean daily prey return per day for the year	-300.2	Estimate coef	-1.003	-0.070	0.156			-0.101	-0.101	0.019	
		Standard error	0.034	0.032	0.031			0.060	0.040	0.049	
		P-value	**<0.001**	**0.036**	**<0.001**			0.096	**0.013**	0.695	
		Model: glm(formula = Mean daily prey return per cat ~area + sex + Cat_tracking_study. **Family =** gaussian (link = "log")									
b. Mean daily prey return per day in dry season	-280.6	Estimate coef	-0.916		0.154			-0.070	-0.100	-0.024	
		Standard error	0.034		0.030			0.056	0.037	0.048	
		P-value	**<0.001**		**<0.001**			0.216	**0.008**	0.623	
		Model: glm(formula = Mean daily prey return per cat per day dry ~ area + sex **+ cat in tracking study**									
		Family: gaussian(link = "log")									

c. Mean daily prey return per day in wet season	-296.1	Estimate coef	-1.094	-0.092	0.166			-0.170	-0.138	0.038	
		Standard error	0.038	0.038	0.035			0.071	0.045	0.054	
		P-value	**<0.001**	**0.016**	**<0.001**			**0.018**	**0.003**	0.482	
		Model: **glm (formula** = Mean daily prey return per cat per day wet ~ area + sex + Cat tracking study.									
		Family: gaussian(link = "log")									

Factors affecting mean daily prey returns of mammals, birds, and reptiles per cat

For the factors that influence total prey returns of the main taxa: mammals, birds, and reptiles; male cats were significantly more likely to return more birds and reptiles (Table 5), with male cats 2 and 3 years old significantly more likely to return mammals compared to females of the same ages. Cats from Ikota had significantly higher daily rates of mammal returns per cat, but significantly lower daily rates of bird and reptile returns compared to Alpha-beach (Figure 5.5). Cats from Barbwire also had a lower rate of reptile returns compared to Alpha-beach (Table 5.6).

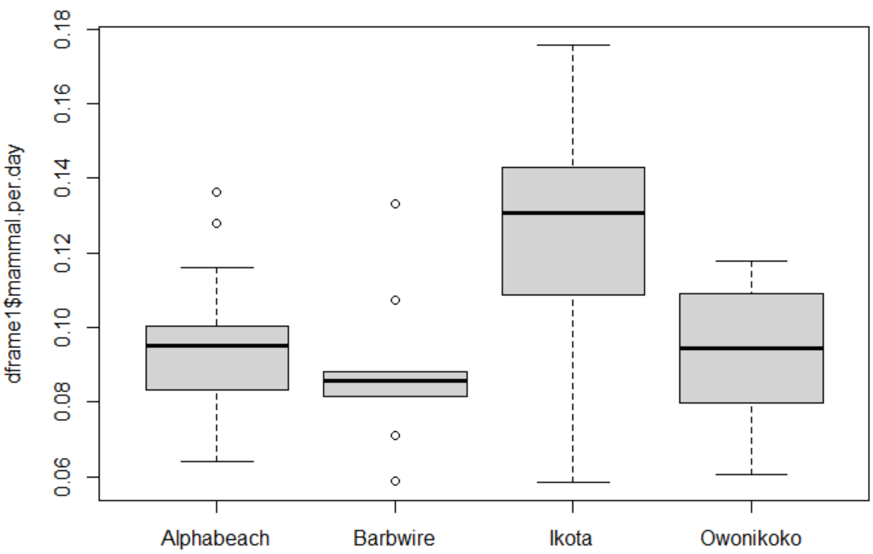

Figure 5.5. Mean mammals return per day by cats according to locations.

Table 5.6: Final general linear models for mean daily prey return for mammals, birds, and reptiles over the year.

	AIC		(Intercept)	Sex		Age		Location			Interaction terms	
				F	M	2	3	Barbwire	Ikota	Owonikoko		age:sex

4. Mammal return rate per day	879.6	Estimate coef	-2.360		-0.054	-0.071	0.004	-0.100	0.243	-0.044		0.283 (C2yr) 0.270 (C3yr)
		Standard error	0.057		0.066	0.059	0.082	0.081	0.056	0.072		0.094 (C2yr) 0.123 (C3yr)
		P-value	**0.0**		0.412	0.234	0.952	0.217	**<0.001**	0.543		**0.003 (C2yr) 0.031 (C3yr)**
		Model: glm(formula = logmammal ~ area + age + sex + age:sex **Family** = gaussian(link = "identity").										
5. Bird return rate per day	-481.8	Estimate coef	-2.180		0.140			-0.014	-0.531	-0.123		
		Standard error	0.064		0.056			0.106	0.071	0.092		
		P-value	**<0.001**		**0.015**			0.899	**<0.001**	0.185		
		Model: glm(formula = logbird ~ area + sex										
		Family: gaussian(link = "identity").										
6. Reptile return rate per day	815.11	Estimate coef	-2.710		0.223	-0.077	-0.186	-0.328	-0.256	-0.074		
		Standard error	0.092		0.073	0.079	0.109	0.139	0.095	0.123		
		P-value	**<0.001**		**0.002**	0.328	0.092	**0.021**	**0.008**	0.549		
		Model: **glm(formula = logreptile ~ area + age + sex**										
		family = gaussian (link = "identity").										

There was significantly higher mammal return rates per day in the dry season (median 0.1245) compared to the wet season (median 0.092; P < 0.001). Birds were also significantly higher in return rates per day in the dry season (median 0.114) compared to the wet season (median 0.069; P < 0.001). However when the areas were considered, there was no significant difference in the mammal and reptiles return rates per day in the dry season compared to the wet season, while there was a significantly higher bird return rate per day in the dry season compared to the wet season (t = 3.994, df = 3, P = 0.028).

5.5 Discussion

The domestic cat is considered to be among the most significant threats to terrestrial biodiversity in many parts of the world, particularly where they are a more recent introduction. Cats are largely associated with human habitation, and as human populations grow, cat populations grow. Nevertheless, while they are seen as of considerable ecological concern, studies have generally taken place in a very limited range of locations, with the majority of studies emerging from the UK, USA, Canada, Australia and New Zealand. Our study is the first to consider cat predation in the continent of Africa outside of South Africa and is one of the few in the tropics or sub-tropics. We examined predation by urban domestic cats in the megacity of Lagos, Nigeria. We found that individual cats varied in the volume of prey returned, with mean daily return rates ranging from 0.1 to 0.64 prey. Mammals and birds were the predominant prey groups (31.3% and 26.6% of prey respectively), with rodents being the predominant (84.7%) mammal prey.

Predation rates were higher in dry seasons, with the mean daily predation rates for the dry and wet seasons being 1.32 and 1.05 respectively. The mean annual predation rate of 412 prey per cat per year is high compared to previous studies, which typically range from 14 to 302 prey per cat per year depending on location (Woods et al., 2003; Kays & DeWan, 2004; Baker et al., 2008; Morgan et al., 2009; Thomas et al., 2012; Loyd et al., 2013; Kays et al., 2020; Seymour et al., 2020; Pirie et al., 2022).

Importantly our study only considers owned domestic (pet) cats and not feral cats. While in many countries the overall effect of feral cats is likely to be lower than pet cats simply because there are fewer, but they will have a greater per capita effect on prey species (Loss et al., 2013; Pillay et al., 2018; Woinarski et al., 2018 and Seymour et al., 2020). With the estimated annual predation rate of 412.45 prey per cat per year the corresponding estimates of mortality caused by free-ranging domestic cats in Lagos based on the cat population range of 122,142.5 – 286,538.0 (Chapter 3) is in the range of 50.3m - 117.7m prey annually. This study thus confirms that domestic cats alone kill a substantial number of prey individuals and may pose a significant threat to urban wildlife in Lagos. Rates of predation may reflect two factors. First, cat owners in Lagos do not feed cats in the manner that pet cats are fed in the western world (Chapter 2), so predation for food is necessary. Second, prey may be more abundant in this tropical region. Together, there is little doubt that domestic cats are likely to be significant predators in parts of West Africa.

We found that prey types are similar to those recorded in other studies, with mammals are the most frequently returned prey, followed by birds (Churcher & Lawton, 1987; Barrat, 1997; Woods et al., 2003; Kays & DeWan, 2004; Baker et al., 2008; Tschanz et al., 2010., Krauze-Gryz et al 2012, Thomas et al. 2012; Loyd et al., 2013; Kays et al., 2020; Pirie et al. 2022), and these are consumed by domestic cats in that order (Liberg, 1984; Weber & Daily, 1998; Biró et al., 2005; Campos et al., 2007; Krauze-Gryz et al 2012; Thomas et al. 2012). Invertebrates made up 13.4% of the prey returned. Geckos constituted the bulk of reptile prey returned and it has been argued that the nocturnal nature of geckos coincides with cat peak feeding time, and their overall abundance in urban areas has renders them vulnerable (Seymour et al., 2020). Krauze-Gryz et al. (2012) found that reptiles were more abundant in the samples of prey eaten rather than in the prey returned home, and Seymour et al. (2020) using camera studies found that reptiles constituted 50% of prey but only 17% of prey returned home. Amphibians (1543; 9.0%) were the least frequently recorded major taxon, agreeing with previous studies, in that amphibians are relatively infrequent or absent among domestic cat prey items brought home or eaten (Liberg, 1984; Churcher & Lawton, 1987; Woods et al., 2003; Biró et al., 2005; Baker et al., 2008; Thomas et al., 2012; Loyd et al., 2013; Kays et al., 2020). However, it should be noted that amphibians are possibly less frequently encountered in urban habitats in Lagos, and moreover, previous studies are in regions where amphibians are relatively uncommon.

Given that we asked volunteers to collect and store prey where possible, and to take smartphone photographs to aid prey identification, we have taken a conservative approach to prey identification. Where there was little doubt as to identification, we have provided species names (Table 5.7 Appendix 5.1), but otherwise we have grouped prey together at high taxonomic levels for analysis. Nevertheless, prey species diversity recorded in this study was not very broad and was typical of urban areas, in that species tolerant of human activity predominated (Luniak, 2004; Baker et al., 2010).

The study examined cat sex and age that may influence predation outcomes by free roaming domestic cats. The sex of the cat did significantly affect the total mean daily rate of prey return as male cats were significantly more likely to return prey compared to females. For the main taxa this was skewed by age as male cats with age 2 and 3 year old cats were significantly more likely to return mammals compared to females of the same age (Table 5.5), and male cats were significantly more likely to return more birds and reptiles. These findings corroborate the findings of Thomas et al (2012) which also uncovered differences in prey return rates between the sexes and similar patterns considering age of male and female cats.

We examined how variation between locations may influence the predation rates exhibited by free roaming cats. We considered living next to purely conserved natural habitat, areas with more patches of green and garden type habitat can affects predation outcomes. We observed that cats from Ikota had a significantly lower mean total daily prey return per cat compared to Alpha-beach, Owonikoko and Barb wire locations (Figure 5.4) and these being habitats more suitable for prey (with higher coverage with natural habitat of patches of green and garden). Coincidentally these locations numerically recorded the largest home ranges with Barbwire directly bordering the Lekki Conservation and suggesting cats resident in the immediate environs of the Lekki conservation natural habitat and the areas with more patches of green and garden type habitats integrates these areas into their home ranges thus increasing predation rates (see also Chapter 3). Thomas et al. (2014) and Pirie et al. (2022) noted that cats would spend proportionately more time in gardens and other green habitats, than in high density urban habitats.

In our study only cats that had free access to outside were incorporated but other studies with part of the cats confined for part of the day have shown that cats with free access to outside all day have higher predation rates (Wood et al. 2003; Thomas et al 2012). Our study found that cats carrying GPS trackers, for both dry and wet seasons, were significantly less likely to return prey than cats that were not tracked. This suggests that situations where cats are wearing collars (whether with GPS units, or anti-predation devices) would have significantly reduced predation rates. Other studies have also confirmed that wearing collar mounted anti-predatory gadgets reduced prey return (Gordon et al. 2010; Thomas et al. 2012).

In conclusion, there is now extensive evidence associating wildlife diversity declines with predation by free-ranging pet cats (Baker et al., 2008; Crooks and Soule, 1999; Sims et al., 2008; Smith et al., 2016; Thomas et al., 2012; van Heezik et al., 2010, Kays et al., 2020 and Seymour et al. 2020) as mortality caused by domestic cats can be substantial for some prey species (Barratt 1998; Baker et al. 2008; Van Heezik et al. 2010; Thomas et al. 2012, Kays et al. 2020).

For the first time, I show that rates of predation by pet cats in urban Lagos are substantial, with perhaps in the region of 100 million vertebrates killed by owned cats in the city alone. Given that feral cats are also abundant, domestic cats are likely to be a significant cause of mortality of small and mid-sized terrestrial vertebrates in West Africa.

Result of studies reassessing predation through collar mounted cameras sources have offer a more reliable measure of cat activities and predation than observation or scat analysis (Loyd et al., 2013; Morling 2014; McGregor et al., 2015; Huck and Watson, 2019; Seymour et al., 2020) and hence future research endeavour in this direction should deploy animal-mounted video systems so that ambiguities associated with free ranging domestic cat behaviour could be adequately quantified.

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Chapter 6.

Country of birth, or country of residence? Influence of life experience on attitudes to conservation and animal welfare using the domestic cat as a case study.

6.1 Abstract

Humans have lived in close association with Cats (*Felis catus*) in various forms both feral and domestic for a long period and having different cultural beliefs and myths associated with cats over time. Cats are now one of the world's most common pets with popularity for companionship vastly increasing in many countries. Feral cats and free-roaming domestic cats are recognised as one of the world's major threats to biodiversity. The growing evidence of the ecological impacts on native fauna through predation and couple with deep rooted societal culture and beliefs affects people attitude towards them. The aim of this study was to explore how residents' perceptions of and attitudes towards domestic cats and feral cats differ between countries and cultures and if responses are likely to be affected by long term interaction with foreign culture and experience resulting from long term migration. A total of 1550 samples, comprising 262 Nigerian nationals residence in UK (NUK), 664 Nigerian nationals residence in Nigeria (NN), 269 UK nationals residence in Nigeria (UKN) and 355 UK nationals residence in UK (UKUK) were surveyed in relation to demographic information, cat ownership status and care, participant interest in wildlife and attitude towards cats in regards to general thoughts on feral and pet cats, risk of disease and lastly participant preferences for management options for feral and owned cats. The findings revealed that companionship was the main reason for owning a cat by UKUK and UKN, however pest control was the most important reason for NUK and NN. The notion that free roaming cats harm wildlife was shared by NN, UKN and UKUK. The UKUK were significantly more likely to agree to the NN position of likely to agree on the attitude statement that feral cats constitute a nuisance. Deep rooted societal culture and beliefs like cats being associated with witches and wizards is deeply rooted within NN and the attendance apathy have strongly affected people's attitudes towards cats in Nigeria. The UKN and UKUK are less likely to agree to this NN position and also as it relates to eating cats. Study reveals the strong need for public awareness on knowledge about cats and cat's management awareness campaign for the general public and cat owners in Nigeria. The management option that all cats should wear collar bells or any other anti-predation gadgets had strong public agreement as the most highly recommended option for potential management of cat's predation, with the UK nationals irrespective of where they live being significantly more likely than Nigerian nationals (N) to strongly agree with the statement that cats should wear bells or any other anti-predation gadgets. Finding also reveal that those born in UK are significantly inclined to strongly agree to the management option of Trap Neuter Return (TNR) irrespective of where they live than Nigeria nationals, but shares the same level of neutrality response to this management opinion. Study observed significant swings in attitude to cats and cats management in many aspects, underpinning that long term interaction with foreign culture and experience resulting from migration between countries and cultures do affect some aspect of people's attitudes and feelings towards cats and being enabled by

underlying factors like policies, persuasiveness of beliefs and inherent cultures, public enlightenment and proactive engagement approaches.

6.2 Introduction

People's attitudes towards animals can seem universal but for some specific animals, deep rooted societal differences in culture and beliefs can influence people's attitudes towards them (Selby and Rhoades 1981; Serpell 1988; Metzer 2009). Cats are one of the world's most common pets, so an understanding of people's attitudes towards them in different locations and under different circumstances becomes not only interesting in itself but given challenges of cats to conservation, this is vital to the crafting of management approaches for cat related issues and any emerging initiatives for managing cat-human relationships Gramza 2015. In this context, attitude has been defined as "a learned predisposition to respond to an object in a consistently favourable or unfavourable way" (Fishbein and Ajzen 1975), and can be formed from a person's past and present Ajzen and Fishbein (1980) suggesting that attitudes and social norms thus predict actions. For example, from the perspective of human-animal interactions (Coleman et al. 2003) showed that those who humanely handled animals were more likely to have positive attitudes to animals (Samia et al. 2012).

6.2.1 Cat predation and people's attitudes.

Research on feral cats and pet cats suggests that the population of cats has increased in most nations, especially in the developed western economies, China, Japan, Australia, and New Zealand (Denny et al. 2010; Lloyd and Hernandez 2012; Hall et al. 2016; Aegerter et al. 2017; Hanmer et al. 2017). Resulting predation projections from various studies (Churcher et al. 1987; Lowe et al 2000; Taylor 2000; Woods et al. 2003; Blackburn et al. 2004; Robinson et al. 2005; Baker et al. 2005; Beckerman 2007; Baker et al. 2008; Sims et al. 2008; Medina et al. 2009; Medina et al. 2011; Thomas et al. 2012; Blancher 2013; Bonnington et al. 2013; Loss et al. 2013; Doherty et al. 2016; Marra et al. 2016; Pirie et al. 2022) has raised serious concerns about cat predation(Galbreath et at 2004). Peoples' response to these realities seems to indicate an increasingly negative attitude towards cats in some areas (Chaseling 2001), though often it provokes strong arguments and opposing perceptions from the viewpoints of others too(DSE 2003). Aside from direct predation of both fauna, diseases can be transmitted by cats to the native carnivores and humans alike (Gethings et al. 1987; Han et al. 199; Brown et al. 2008; Deplazes et al 2011; Gerhold and Jessup 2013; Greenblatt et al 2013). The Australian Department of Sustainability and Environment (DSE 2003) pointed out that across the cat owners and non-cat owners divide, a greater percentage of respondents agreed to the statement that domestic cats predation on wildlife in the suburb is an issue and generally supported government control legislation (Kays et al 2004;Samia et al. 2012). Nevertheless, very few studies have focused on general public opinions and their perceptions of cats and knowledge about cats (Lloyd and Hernandez 2012; Loyd et al. 2013).

6.2.2 People's attitudes towards cat management.

The role of people's attitudes in the management of introduced wildlife cannot be over-emphasized (Dickman 1996; Bremner and Park 2007; Liu et al. 2011), as people with different cultural backgrounds and/or demographics might perceive things differently. The Australian DSE (2003) highlights that cat owners and non-owners differed in attitudes towards cat containment and wildlife. The few studies on attitudes towards cat's reveals a higher percentage of respondents reporting issues such as damage to gardens, nuisance noise (especially during brawls) and wildlife predation (Perry 1999; Samia et al. 2012). Understanding of the prevalence and diversity of different attitudes towards cats and their control, will allow the development of broadly acceptable management approaches that will ensure minimal conflict with stakeholders (Serpell 2004; Russell 2014). Contemporary management decisions requires the public to be fully involved, thus understanding the baseline attitudes is paramount (Lawrence et al. 2019). Fitzgerald et al. (2007) and Fitzgerald's (2009) studies on attitudes to introduced wildlife and their impacts in Australia suggests that attitudes differed between people varying in gender, type of residence, age and income level (Russell 2014). Typical is the fact that women are seen to put greater value on compassion and protection of individual animals than men (Miller & Jones 2006). Oftentimes government agencies in charge of formulating policies on cat management do not have the requisite information on underlying beliefs, knowledge and experience that might shape the public preference for a preferred cat management option (Lloyd and Hernandez 2012; Redpath 2012).

6.2.3 Culture and people's attitudes towards cats.

Cats were associated with witches and wizards during the middle Ages in Europe and connected with demonic devotions (James 2000). In Nigeria the belief is that witches are associated with cats, and that cats are used by witches and wizards to cause havoc and other evils in society, as wizards and witches prefer to use cats as their spiritual transformation medium using their mystic power (Bukar-Kolo et al. 2018). Recently in another part of my research work (Chapter 4), a spiritualist and traditional medicine man confirmed this position when he said that his cats could not be recruited for tracking because he uses his cats for spiritual errant. This attitude and belief system also held sway in medieval UK, when cats had a reputation being associated with witchcraft (Metzer 2009). Shape-shifting into cats were commonly associated with witches and was also believed that cats had the devil's spirit within.

In this study we examined differences in attitudes towards cats and cat management between two divides with a highly novel perspective. By comparing the attitudes of Nigerian and British nationals both in their home country, and having moved to the non-home country, we can examine how attitudes to the significant conservation question of cat predation may differ between countries and cultures and if responses are likely to be affected by long term interaction with foreign culture and experience. Together, these will help us understand how cultural differences may determine the appropriate approaches to reducing the impact of cats on wildlife.

6.3 Methods

6.3.1 Study Area

The study was carried out in Lagos (Nigeria) and Reading and London (United Kingdom). Lagos is the most densely populated city in Nigeria with an area of 1,171 km² and with an estimated population of 21m people (Rosenthal 2012; Punch New 2018). Nigeria is ranked the seventh most populous country in the world. The city of Lagos is located at the Southwestern Geopolitical zone of Nigeria (6°27′ 14.65″ N, 3°23′ 40.81″ E). Data were collected from Nigerian households in the Lagos megacity and other cities in Nigeria. The locations that captured the perspective for Nigerians resident in Britain and UK residents in Britain were in some parts of Greater London: Peckham (51.4703 ° N, 0.0674° W) with an area of 5.6km^2) and an estimated population of 14,720,552 (UK census 20112011 census). Hackney (51.5734° N, 0.0724° W) with an area of 19.06km^2 and an estimated population of 275,929 (ONS UK, 2017), Brixton (51.4613° N, 0.1156° W) with an area of 4.3km and an estimated population of 78,536(UK census 2011) and in Reading, UK (51°27′N, 0°58′W) with an area of 55km^2 and a population estimate of 155,700 people (National statistics 2011).

6.3.2 Questionnaire

We examined differences in people's attitudes between countries (in this case Nigeria and the UK) to help gain an understanding of how attitudes towards cats and responses towards management options may differ. In designing the survey questionnaire, I adapted questions from previous studies (Lloyd and Hernandez 2012; Thomas et al. 2012; see Chapter 2 which focus only on Nigerian attitude). The questionnaire survey was divided into four different sections: (1) Demographic information (10 questions); (2) Cat ownership status (9 questions), and (3) Participants' attitudes towards cats in regards to general thoughts on feral and pet cats, and risk of disease and towards wildlife which was determined on a five-point Likert scale (Likert 1932; 16 questions) and (4) Participant preferences for management options for feral and owned cats also on a five-point Likert scale, in response to a preliminary declaration: "If it is found that cats are affecting wildlife, and management decisions have to be made to reduce this, please indicate whether you strongly agree, agree, neutral, disagree, strongly disagree to these management options" (12 questions; Appendix 3). The questionnaire was pre-tested by 30 volunteers for understanding of phrasing and content and it took each person approximately 10-15 minutes to complete the questionnaire. Only participants who were above 18 years of age qualified to enter in the survey. The project was subject to ethical review according to the procedures specified by the University of Reading Ethics committee and has been given favourable ethical opinion for conduct. The study was approved by the University of Reading School of Biological Sciences ethical review committee (reference SBS16-17 18).

6.3.3 Data collection

Data collection was conducted using door-to-door sampling on the Crowdsignal application (Crowdsignal 2008) questionnaire saved on iPads. Also, an online survey was performed using the link: https://pawrg.polldaddy.com/s/global-cattitudes-survey from the Crowdsignal application, where we asked people to pass on to friends, colleagues and relatives and other respondents in Nigeria who were contacted via email and social media. Printed hard copies were left with some household members who were not ready to participate immediately and in some offices which were collected a few days later. For British people living in Nigeria efforts were focused on sharing the questionnaires in multinational companies located in Victoria Island, Lagos and recreational hotspots like the beaches, beach markets and mega shopping malls in Lekki using hard copies and the Crowdsignal on iPads.

In the UK we targeted churches, mosques and as well as streets in Peckham, Brixton and Hackney central areas to get a range of people from Nigeria. For British people in Britain this was done through door-to-door sampling using a Crowdsignal application (Crowdsignal 2008) questionnaire saved on iPads.

6.3.4 Data analysis

We considered four broad groups of responders, based on country of birth and residence until adulthood (Nigeria or UK), and place of residence as an adult (again, Nigeria or UK). This provides four groups: Nigerian nationals in Nigeria (hereafter NN), Nigerians in the UK (NUK), UK nationals in Nigeria (UKN) and UK nationals in the UK (UKUK). The questions used in the analysis were not set as being compulsory and hence not all respondents answered all questions and as such sample sizes vary. An ordinal logistic regression and Cumulative Link Model (CLM) in the R statistical Software (R Core Team 2018, version 3.5.1, package: ordinal) was used initially, however models violated the parallel lines assumption so a multinomial logistic regression was used instead (R Core Team 2018, version 3.5.1, package: nnet). We investigated the effect of nationality (Nigerian or British) and country of residence (Nigeria or UK) on response to the various attitude questions and management decision options (five possible responses on a Likert scale; strongly agree to strongly disagree; dependent variables) about free roaming and feral cats in both cases. In addition to born and live, full models also included the independent variables; age (18-

25, 26-35, 36-45, 46-55, 56-65, over 65), gender (male or female), employment (unemployed, student, retired, working part time, working full time), and cat ownership (yes or no). Fourteen models per question were compared including the global model and null model, models with and without interactions between born and live. The model with the lowest AIC values were considered the best model for each question.

6.4 Results

Data were collected from a total of 1550 respondents which was made up of: NN: 664 respondents; NUK: 262 respondents, UKN 269 respondents; and UKUK 355 respondents. Out of the 1550 overall survey participants, the predominant age group was 26-35 (Figures 6.1), with 2.5% more female respondents than male (Figures 6.2) and 73.3% were in employment. There were 295 respondents (19%) that owned a cat, with UKUK having the highest cat ownership and UKN had the lowest cat ownership (Table 6.2). UKUK also had the highest amount of neutered cats with NN having the lowest, however NUK showed a possible change in attitude with 50% being neutered (Table 6.2). NN had fewer cats wearing bells or other anti-predation collars whereas UKUK had 57.7% (Table 6.2).

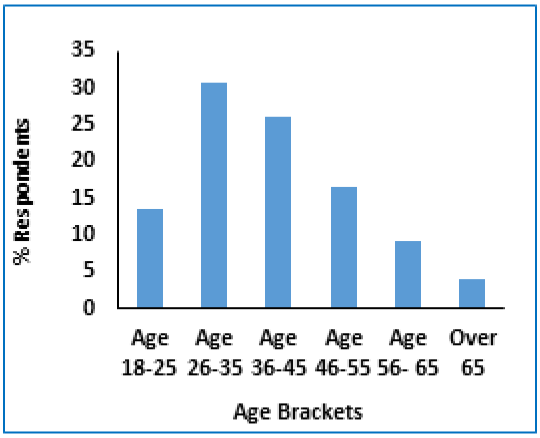

Figure 6.1: Combined participant's age groupings% participation

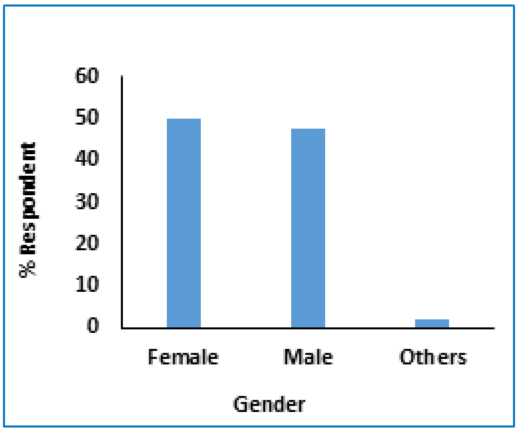

Figure 6.2: Combined gender % participation.

Table 6.1: Cat ownership and rates of cat neutering and collar wearing.

Category	Total number participants	Cat owners (%)	Cats neutered (%)	Cats wearing collar (%)
NN	664	15.5	6.8	5.9
NUK	262	10.7	50.0	89.3
UKUK	355	29.3	84.6	57.7
UKN	269	7.4	35.0	65.0

Companionship was the main reason for owning a cat by UKUK and UKN (Figure 6.3) however pest control was the most important reason for NUK and NN. Reasons for not owning cats is given (Table 6.3 Appendix-6.1).

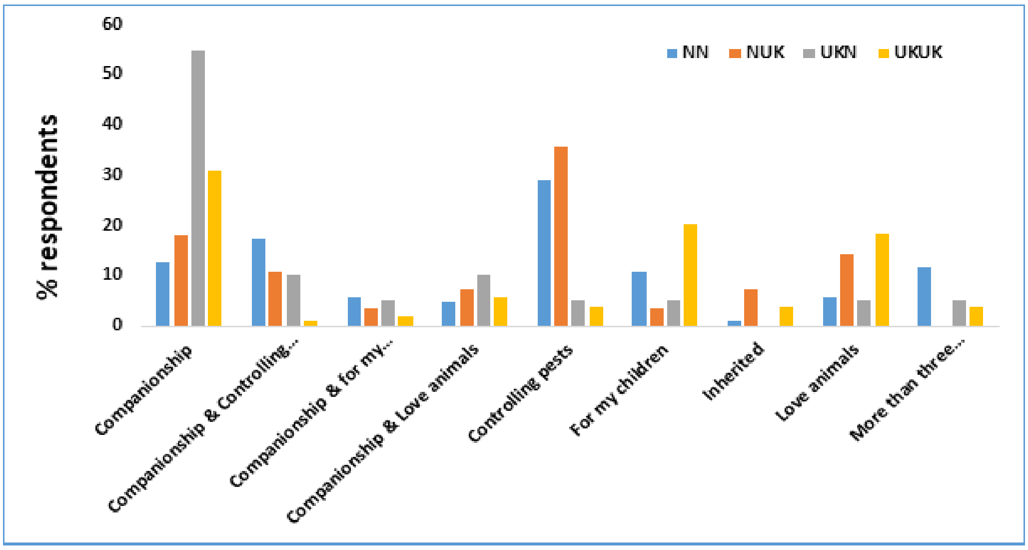

Figure 6.3: Reasons for owning cats NN, NUK, UKN & UKUK.

6.4.1 Attitudes and beliefs towards free roaming and feral cats

All the best models for the attitude questions contained country of birth, country of residence and the interaction between both. Owning a cat was an important factor for people responding to the statement that feral cats have a right to live in the neighbourhood. Age and owning a cat were also found to be significant factors for two questions; the risk of contracting a disease from a cat was low and cats make good pets (Table 6.2A). The model for cats controlling pests in the local area did not contain any significant elements.

NN are significantly more likely to strongly agree than strongly disagree (OR 2.71) that feral cats have the right to live in the neighbourhood and although the NUK are also more likely to strongly agree than strongly disagree, it was not significant. For UK nationals, UKN are significantly less likely to strongly agree than strongly disagree (OR 0.12) that feral cats have the right to live in the neighbourhood showing a more extreme attitude, but the UKUK are not as inclined to strongly disagree (Figure 6A1; Table 6.2A).

UKUK are significantly more likely to strongly agree or agree than strongly disagree (OR 3.96 and OR 132.86 respectively) that the risk of contracting a disease from a feral cat is low, but UKN are significantly less likely to strongly agree than strongly disagree (OR 0.03) again showing a more extreme attitude. While NN are significantly more likely to agree than strongly disagree (OR 2.34), NUK are significantly more likely to be neutral than strongly disagree (OR 5.50) showing a reduced extreme attitude compared to NN (Figure 6A2; Table 6.2A).

NN are significantly more likely to strongly agree than strongly disagree (OR 2.50) that feral cats are a nuisance. However NUK become less extreme and are significantly more likely to be neutral than strongly disagree (OR 10.37) where as UKN become more extreme in their view point being significantly more likely strongly agree than strongly disagree (OR 12.36) that feral cats are a nuisance (Figure 6A3; Table 6.2A).

NN are significantly more likely to strongly agree or agree than strongly disagree that free-roaming cats harm wildlife (OR 16.00 and OR 7.05) but this is not shown by UKUK people. Although NUK are significantly more likely to strongly agree than strongly disagree, it is to a lesser extent than NN (OR 1.85; Figure 6A4; Table 6.2A).

UKUK are less likely to agree than strongly disagree that it is acceptable to eat cats but their counterparts in Nigeria (UKN) are significantly more likely to be neutral (OR 1.57) though still significantly less likely to strongly agree than strongly disagree (OR 0.01; Figure 6A5; Table 6.2A). NN are significantly more likely to strongly agree than strongly disagree (OR 1.78) that it is acceptable to eat cats but their counterparts NUK are significantly less likely to strongly agree than strongly disagree and are more likely to be neutral too (OR 0.40 and OR 1.57 respectively).

For the attitude question that cats are associated with witchcraft, UKUK are significantly less likely to strongly agree or agree than strongly disagree (OR 0.01 and OR 0.09 respectively) but UKN are significantly more likely to be overwhelmingly neutral (OR 4.12) and significantly less likely to strongly agree than strongly disagree (OR 0.19) Figure 6A6; Table 6.2A). NN are significantly more likely to strongly agree than strongly disagree (OR 9.03) that cats are associated with witchcraft, but NUK have reduced strongly agree or agree than strongly disagree response (OR 2.00 and 1.40 respectively; Figure 6A6; Table 6.2A).

For question positing that cats are harmless UKUK are significantly more likely to strongly agree or agree than strongly disagree (OR 2.14 and OR 27.01 respectively), but UKN are significantly less likely to strongly agree or agree than strongly disagree (OR 0.17 and 0.42 respectively; Figure 6A8; Table 6.2A). NN again show more extreme views although they are significantly more likely to strongly agree than strongly disagree (OR 2.00) but NUK are significantly more likely to agree or be neutral (OR 3.45 and OR 4.40 respectively) than strongly disagree about cats being harmless (Figure 6A8; Table 6.2A).

NN and UKUK are significantly more likely to strongly agree than strongly disagree (OR 6.09E+7 and 2.77E+8 respectively) that cats makes good pets, but for NUK, although still significantly more likely to strongly agree or agree than strongly disagree (OR 1.06 and 2.68), this difference is reduced and instead shows an increase in a neutral response to the statement that cats make good pets (OR 2.07; Figure 6A9; Table 6.2A). UKN shows a similar adjustment although they are significantly less likely to strongly agree than strongly disagree (OR 0.96) and are significantly more neutral (OR 9.13) than strongly disagree (Figure 6A9; Table 6.2A).

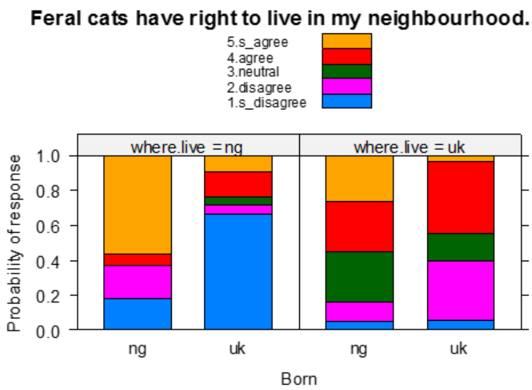

Figure 6.A1

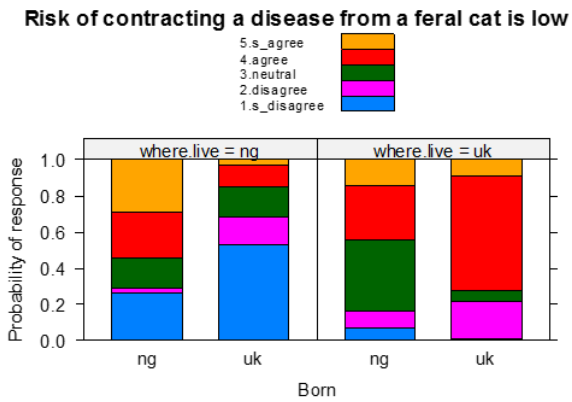

Figure 6.A2

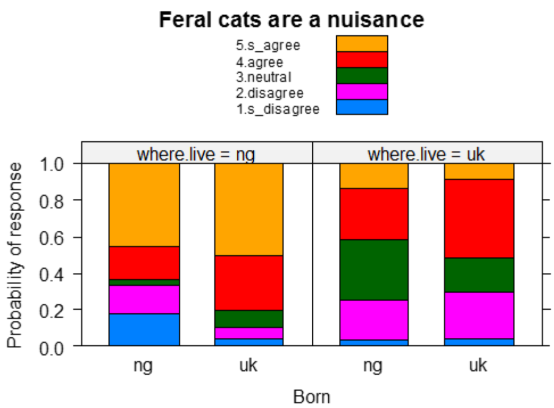

Figure 6.A3

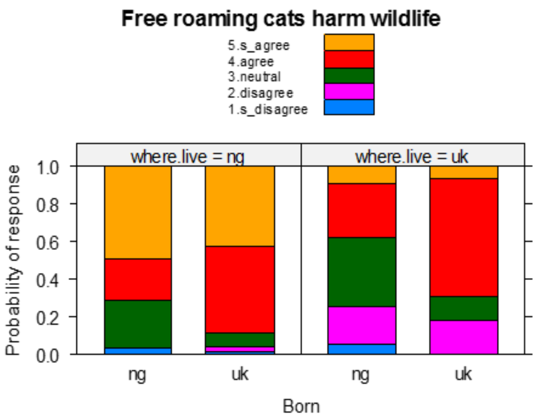

Figure 6.A4

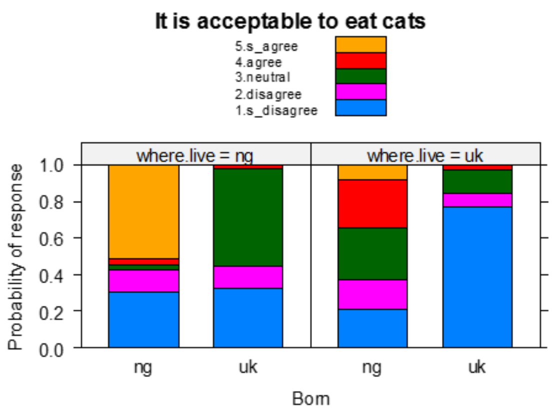

Figure 6.A5

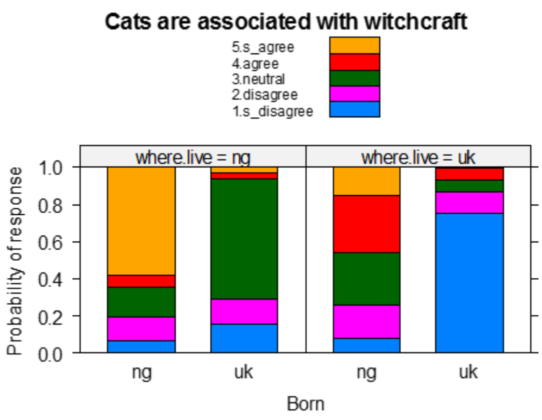

Figure 6.A6

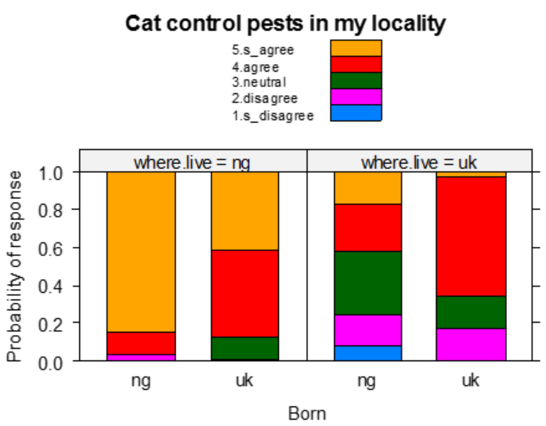

Figure 6.A7

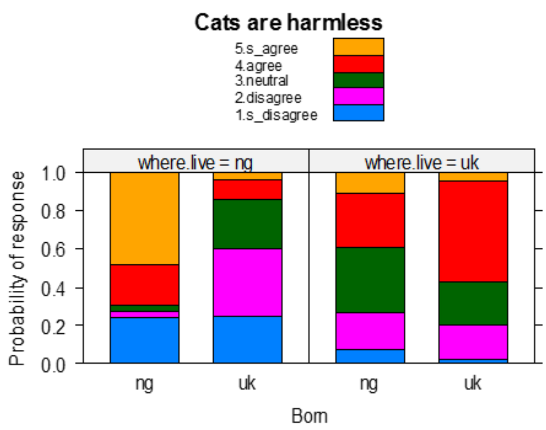

Figure 6.A8

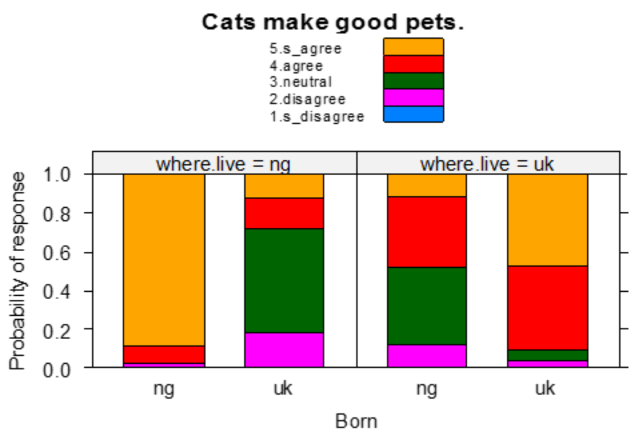

Figure 6.A9

Figures 6.A1 to 6.A9: Modelled probabilities for each response (strongly agree (s_agree), agree, neutral, disagree, strongly disagree (s_dissagree) to each statement by the four different categories of nationality and country of residence (NG = Nigerian / Nigeria, UK = British / UK).

Table 6.2A: The true log odds and [odds ratios] for each variable within the best model for the responses to each of the attitude questions (SA = strongly agree, A = agree, N = neutral, D = disagree, SD = strongly disagree). Significance ($p<0.05$) is indicated by bold values. A tick indicates the variable was present in the best model and a cross indicates it was not.

Response (Ref = SD)	**Intercept (Born: Ng, Live: Ng)**	**Born (Born: UK, Live: Ng)**	**Live (Born: Ng, Live: UK)**	**Born:Live (Born: UK, Live: UK)**	**Cat (Ref=No)**	**Age level (Ref level=18-25 years)**				
						(26-35)	**(36-45)**	**(46-55)**	**(56-65)**	**(65 +)**
Q1. Feral cats have the right to live in my neighbourhood										
	✓	✓	✓	✓	✓	✕	✕	✕	✕	✕
SA	**0.994 [2.702]**	**-2.106 [0.122]**	1.545 [4.688]	**-0.570 [0.565]**	**1.852 [6.372]**					
A	**-1.199 [0.301]**	-1.666 [0.189]	**1.625 [5.078]**	1.806 [6.084]	**-0.396 [0.673]**					
N	**-16.201 [0.000]**	**-2.751 [0.064]**	**1.683 [5.381]**	**0.894 [2.444]**	-15.809 [0.000]					
D	-0.065 [0.937]	**-2.774 [0.062]**	**0.714 [2.042]**	**1.646 [5.187]**	**0.573 [1.773]**					
Q2. The risk of contracting a disease from a cat is low										
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SA	**-0.557 [0.573]**	**-3.551 [0.029]**	**0.075 [1.078]**	**1.377 [3.961]**	-0.108 [0.898]	**0.116 [1.123]**	**0.057 [1.059]**	-0.031 [0.969]	**0.615 [1.850]**	0.185 [1.203]
A	**0.849 [2.337]**	**-0.571 [0.565]**	**2.367 [10.665]**	**4.889 [1.32E+02]**	**1.581 [4.859]**	1.048 [2.852]	**1.431 [4.183]**	**1.515 [4.552]**	**1.698 [5.462]**	1.361 [3.899]
N	**-0.520 [0.595]**	**-1.216 [0.297]**	**1.705 [5.504]**	1.713 [5.546]	**0.109 [1.116]**	-0.675 [0.509]	-0.508 [0.602]	-0.346 [0.707	-1.038 [0.354]	-0.706 [0.494]
D	**-1.993 [0.136]**	**-1.131 [0.323]**	**0.407 [1.502**	**3.002 [0.111]**	-1.933 [0.145]	-2.198 [0.111]	-2.014 [0.133]	-1.999 [0.135]	-2.806 [0.060]	-1.972 [0.139]
Q3 I feel feral cats are a nuisance										
	✓	✓	✓	✓	✕	✕	✕	✕	✕	✕
SA	**0.916**	**2.515**	1.476	**0.795**						

	[2.500]	**[12.363]**	[4.375]	**[2.214]**						
A	0.016 [1.017]	**1.984 [7.272]**	**2.140 [8.500]**	**2.391 [10.928]**						
N	**-1.792 [0.167]**	**0.821 [2.273]**	**2.339 [10.375]**	**1.535 [4.643]**						
D	-0.163 [0.850]	0.435 [1.546]	**1.928 [6.875]**	1.883 [6.571]						
Q4. Free-roaming cats harm wildlife										
	✓	✓	✓	✓	✗	✗	✗	✗	✗	✗
SA	**2.773 [16.000]**	3.350 [28.502]	**0.613 [1.846]**	11.693 [1.20E+5]						
A	**1.953 [7.050]**	**3.426 [30.754]**	1.726 [5.615]	13.909 [1.10E+6]						
N	**2.098 [8.150]**	1.558 [4.751]	1.935 [6.923]	12.344 [2.30E+5]						
D	-12.905 [0.000]	0.559 [1.748]	1.367 [3.923]	12.674 [3.19E+5]						
Q5. It is acceptable to eat cats										
	✓	✓	✓	✓	✓	✗	✗	✗	✗	✗
SA	**0.575 [1.777]**	**-4.402 [0.012]**	**-0.915 [0.401]**	-5.479 [0.004]	0.286 [1.332]					
A	**-2.232 [0.107]**	-2.594 [0.075]	**0.301 [1.351]**	-3.131 [0.044]	-2.713 [0.066]					
N	**-2.142 [0.117]**	**0.614 [1.88]**	**0.449 [1.566]**	-1.701 [0.183]	**-3.001 [0.050]**					
D	**-0.813 [0.444]**	-0.885 [0.413]	**-0.194 [0.824]**	-2.243 [0.106]	**-1.357 [0.258]**					
Q6. Cats are associated with witchcraft										
	✓	✓	✓	✓	✗	✗	✗	✗	✗	✗
SA	**2.200 [9.025]**	**-1.658 [0.190]**	**0.693 [2.000]**	**-4.837 [0.008]**						

A	**0.025 [1.025]**	**-1.540 [0.214]**	**1.399 [4.053]**	**-2.485 [0.083]**						
N	0.916 [2.500]	**1.416 [4.119]**	1.290 [3.631]	**-2.438 [0.087]**						
D	**0.706 [2.025]**	**-0.182 [0.833]**	0.884 [2.421]	**-1.816 [0.163]**						
Q7. Cats control pests in my locality										
	✓	✓	✓	✓	✕	✕	✕	✕	✕	✕
SA	11.504 [9.92E+4]	4.720 [112.220]	0.794 [2.212]	2.296 [9.930]						
A	9.567 [1.43E+4]	4.815 [123.360]	1.181 [3.259]	5.401 [221.520]						
N	0.243 [1.27]	3.437 [31.097]	1.463 [4.319]	4.120 [61.529]						
D	8.217 [3.70E+3]	0.698 [2.009]	0.815 [2.260]	4.071 [58.624]						
Q8. Cats are harmless										
	✓	✓	✓	✓	✕	✕	✕	✕	✕	✕
SA	**0.693 [2.000]**	**-1.792 [0.167]**	0.371 [1.450]	**0.693 [2.143]**						
A	-0.133 [0.876]	**-0.857 [0.424]**	**1.238 [3.450]**	**-0.133 [27.005]**						
N	**-2.086 [0.124]**	**0.044 [1.045]**	**1.482 [4.400]**	**-2.086 [11.145]**						
D	**-2.086 [0.124]**	**0.364 [1.439]**	**0.854 [2.350]**	**-2.086 [9.431]**						
Q9. Cats make good pets										
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SA	**17.925 [6.09E+7]**	**-0.041 [0.960]**	**0.058 [1.060]**	**19.439 [2.77E+8]**	34.575 [1.04E+15]	17.696 [4.84E+7]	17.523 [4.07E+7]	19.442 [2.78E+8]	19.030 [1.84E+8]	17.832 [5.55E+7]
A	**15.507**	**0.031**	**0.986**	**19.216**	31.651	15.537	**15.411**	17.217	16.798	15.545

	5.43E+6]	**[1.031]**	**[2.682]**	**[2.21E+8]**	[5.57E+13]	5.59E+6]	**[4.93E+ 6]**	[3.00E+ 7]	[1.97E+7]	[5.64E+6]
N	**-5.553 0.004**	**2.211 [9.128]**	**2.067 [7.903]**	**18.122 [7.42E+7]**	9.405 [1.22E+4]	-5.970 [0.003]	-5.977 [0.003]	-5.507 [0.004]	-6.437 [0.002]	-6.756 [0.001]
D	**14.733 [2.50E+6]**	**0.625 [1.868]**	**0.326 [1.385]**	**17.320 [3.33E+7]**	29.788 [8.65E+12]	14.813 [2.71E+ 6]	14.744 [2.53E+ 6]	15.502 [5.40E+ 6]	15.147 [3.79E+6]	13.224 [5.54E+5]

Table 6.2B: The true log odds and [odds ratios] for each variable within the best model for the responses to each of the management questions (SA = strongly agree, A = agree, N = neutral, D = disagree, SD = strongly disagree). Significance (p<0.05) is indicated by bold values. A tick indicates the variable was present in the best model and a cross indicates it was not.

Response (Ref = SD)	**Intercept (Born:Ng, Live: Ng)**	**Born (Born:UK, Live: Ng)**	**Live (Born:Ng, Live: UK)**	**Born:Live (Born: UK, Live: UK)**	**Cat (Ref =No)**	**Age level (Ref level=18-25 years)**					**Employment level (Ref level =Full time)**			
						(26-35)	**(36-45)**	**(46-55)**	**(56-65)**	**(65 +)**	**(emp part)**	**(emp ret)**	**(emp stu)**	**(emp unem)**
Q1 No one residing in a town or city should be permitted to own a cat														
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SA	0.107 [1.113]	**-1.377 [0.252]**	0.427 [1.533]	**1.876 [6.527]**	**-2.204 [0.110]**	0.622 [1.862]	-0.246 [0.782]	-0.411 [0.663]	0.107 [1.113]	0.451 [1.569]	0.200 [1.221]	0.774 [2.169]	-0.486 [0.615]	0.543 [1.722]
A	0.386 [1.472]	**-1.315 [0.268]**	**0.992 [2.697]**	**2.274 [9.723]**	**-2.584 [0.075]**	0.918 [2.505]	-0.086 [0.917]	-2.130 [0.119]	0.205 [1.228]	2.686 [14.670]	0.490 [1.632]	0.801 [2.228]	**-0.399 [0.671]**	0.451 [1.569]
N	**0.673 [1.960]**	**1.530 [4.618]**	**1.709 [5.524]**	**1.073 [2.926]**	**-0.938 [0.391]**	0.269 [1.308]	**-0.308 [0.735]**	**-0.446 [0.640]**	**-0.491 [0.612]**	0.536 [1.709]	1.103 [3.013]	0.826 [2.284]	0.220 [1.246]	1.052 [2.864]
D	**1.402 [4.064]**	1.102 [3.010]	1.411 [4.099]	1.564 [4.779]	**0.245 [1.277]**	0.962 [2.617]	0.828 [2.288]	0.969 [2.637]	1.113 [3.045]	1.270 [3.562]	1.447 [4.252]	1.392 [4.023]	**0.709 [2.031]**	**0.857 [2.356]**
Q2. People residing in ecologically sensitive areas should not be permitted to own cats.														
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✕	✕	✕	✕
SA	**1.152 [2.684]**	0.846 [2.834]	**0.720 [1.311]**	**1.340 [11.239]**	**1.436 [0.669]**	1.152 [3.166]	0.846 [2.331]	0.720 [2.054]	1.340 [3.818]	1.436 [4.205]				
A	**1.528 [4.609]**	**0.153 [1.165]**	1.301 [3.674]	**2.494 [12.104]**	**-0.410 [0.664]**	1.839 [6.288]	1.712 [5.541]	1.219 [3.385]	1.627 [5.087]	1.746 [5.733]				
N	**1.252 [6.242]**	1.207 [8.554]	1.179 [6.083]	0.718 [5.310]	**1.254 [2.386]**	1.252 [3.499]	1.207 [3.342]	1.179 [3.252]	0.718 [2.050]	1.254 [3.503]				
D	**0.330 [2.642]**	0.423 [1.897]	**0.482 [1.390]**	0.920 [1.526]	**1.541 [1.619]**	1.490 [2.509]	1.752 [4.669]	1.860 [4.436]	0.330 [5.766]	0.423 [6.423]				

Q3. All cat should wear collar bells or any other anti-predation gadgets														
	✓	✓	✓	✓	✓	✕	✕	✕	✕	✕	✕	✕	✕	✕
SA	**0.801 [2.227]**	**3.869 [47.903]**	0.631 [1.880]	**2.074 [7.955]**	0.258 [1.295]									
A	**2.307 [10.045]**	**4.473 [87.599]**	**1.460 [4.304]**	2.888 [17.966]	**0.790 [2.204]**									
N	**2.100 [8.164]**	2.318 [10.151]	1.579 [4.852]	1.484 [4.412]	1.625 [5.080]									
D	**1.276 [3.581]**	1.187 [3.277]	**0.551 [1.735]**	0.157 [1.171]	1.614 [5.021]									
Q4. Cats should not be permitted out during the day														
	✓	✓	✓	✓	✓	✕	✕	✕	✕	✕	✓	✓	✓	✓
SA	-0.247 [0.781]	-0.126 [0.882]	-0.007 [0.993]	0.936 [2.551]	**-1.015 [0.362]**						0.045 [1.046]	-0.184 [0.832]	-1.013 [0.363]	0.186 [1.204]
A	**0.985 [2.678]**	**0.246 [1.279]**	1.146 [3.146]	**1.844 [6.322]**	**-0.664 [0.515]**						1.249 [3.486]	0.790 [2.203]	0.352 [1.422]	0.782 [2.185]
N	**1.771 [5.878]**	**2.374 [10.738]**	1.426 [4.162]	1.552 [4.721]	**0.486 [1.626]**						1.752 [5.765]	1.430 [4.179]	1.362 [3.905]	**1.156 [3.176]**
D	**1.654 [5.227]**	1.618 [5.045]	**1.113 [3.043]**	0.753 [2.123]	**1.050 [2.858]**						1.821 [6.176]	1.563 [4.774]	**1.017 [2.764]**	**0.866 [2.378]**
Q5. Cats should not be permitted out at night														
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SA	0.652 [1.919]	**2.447 [11.558]**	0.026 [1.026]	0.996 [2.709]	**-0.338 [0.713]**	1.170 [3.221]	1.012 [2.751]	0.481 [1.617]	0.615 [1.850]	0.681 [1.975]	1.347 [3.847]	1.238 [3.447]	0.108 [1.114]	0.545 [1.725]
A	**0.845 [2.328]**	1.522 [4.582]	**0.247 [1.280]**	0.821 [2.272]	**-0.067 [0.935]**	**1.869 [6.483]**	**1.764 [5.838]**	1.610 [5.003]	1.111 [3.037]	1.908 [6.741]	1.526 [4.602]	0.664 [1.942]	0.831 [2.296]	**0.156 [1.169]**

N	**1.396 [4.038]**	**3.009 [20.720]**	0.899 [2.458]	**0.532 [1.703]**	**0.208 [1.232]**	**2.233 [9.326]**	1.996 [7.363]	1.595 [4.930]	1.385 [3.995]	1.311 [3.711]	**2.276 [9.735]**	1.442 [4.231]	1.301 [3.674]	0.878 [2.405]
D	0.643 [1.902]	1.170 [3.221]	0.157 [1.170]	-0.181 [0.835]	**0.018 [1.018]**	1.464 [4.324]	1.353 [3.868]	**1.764 [5.833]**	1.508 [4.519]	1.299 [3.664]	1.288 [3.626]	0.613 [1.846]	0.514 [1.673]	**-0.675 [0.509]**
Q6. Cats should be registered with the local government council														
	✓	✓	✓	✓	✓	✕	✕	✕	✕	✕	✓	✓	✓	✓
SA	**3.834 [46.241]**	**16.456 [1.40E+07]**	**2.324 [10.212]**	**3.119 [22.634]**	**2.712 [15.062]**						2.890 [17.997]	3.119 [22.614]	2.813 [16.658]	2.956 [19.223]
A	**4.873 [130.649]**	**16.424 [1.36E+07]**	**2.791 [16.301]**	**3.411 [30.292]**	4.125 [61.895]						3.969 [52.922]	3.660 [38.877]	**3.571 [35.561]**	**3.515 [33.620]**
N	**4.023 [55.881]**	**14.545 [2.07E+06]**	**2.794 [16.341]**	**1.664 [5.279]**	3.804 [44.893]						3.345 [28.362]	2.751 [15.654]	3.508 [33.396]	3.118 [22.612]
D	**2.523 [12.471]**	**12.636 [3.07E+05]**	1.958 [7.085]	**1.021 [2.776]**	1.702 [5.484]						2.124 [8.361]	**0.472 [1.604]**	2.281 [9.789]	1.627 [5.090]
Q7. Cats should be neutered														
	✓	✓	✓	✓	✓	✕	✕	✕	✕	✕	✓	✓	✓	✓
SA	**3.019 [20.477]**	**4.724 [112.590]**	**0.418 [1.519]**	2.596 [13.411]	**1.309 [3.703]**						3.204 [24.635]	3.985 [53.781]	**1.804 [6.076]**	**1.922 [6.837]**
A	**3.936 [51.206]**	4.322 [75.341]	**1.402 [4.063]**	2.319 [10.166]	**2.569 [13.052]**						4.250 [70.106]	4.496 [89.629]	**2.837 [17.059]**	**2.652 [14.181]**
N	**2.592 [13.352]**	2.993 [19.936]	**1.445 [4.240]**	1.242 [3.463]	**1.805 [6.078]**						2.569 [13.052]	3.184 [24.153]	2.562 [12.959]	**1.755 [5.782]**
D	**2.016 [7.506]**	2.582 [13.227]	**1.193 [3.296]**	1.187 [3.277]	**1.256 [3.513]**						2.335 [10.325]	1.894 [6.645]	1.355 [3.875]	**0.965 [2.624]**
Q8. More effective management of cats is needed														

	✓	✓	✓	✓	✓	✕	✕	✕	✕	✕	✓	✓	✓	✓
SA	**3.153 [23.410]**	**5.420 [225.974]**	**2.125 [8.374]**	3.458 [31.755]	**1.356 [3.881]**						2.739 [15.474]	2.423 [11.279]	2.412 [11.159]	3.143 [23.163]
A	**4.118 [61.426]**	5.460 [235.086]	**3.023 [20.544]**	4.088 [59.631]	**1.954 [7.058]**						3.535 [34.288]	**2.655 [14.223]**	2.938 [18.870]	3.762 [43.018]
N	**3.043 [20.971]**	1.972 [7.188]	2.445 [11.530]	1.700 [5.473]	**1.659 [5.253]**						2.877 [17.766]	2.450 [11.584]	2.747 [15.594]	3.231 [25.294]
D	**3.000 [20.082]**	**0.131 [1.140]**	**1.530 [4.617]**	-0.328 [0.720]	2.740 [15.481]						3.071 [21.562]	2.247 [9.459]	3.074 [21.618]	2.984 [19.670]
Q9. Euthanizing feral cats is not acceptable														
	✓	✓	✓	✓	✓	✕	✕	✕	✕	✕	✓	✓	✓	✓
SA	**1.397 [4.042]**	**-0.245 [0.783]**	0.688 [1.991]	0.071 [1.073]	1.423 [4.151]									
A	**2.177 [8.817]**	**0.668 [1.951]**	1.719 [5.581]	0.723 [2.061]	1.789 [5.981]									
N	**1.856 [6.400]**	**2.764 [15.860]**	1.932 [6.901]	**1.275 [3.577]**	**0.847 [2.332]**									
D	**0.997 [2.711]**	0.202 [1.224]	0.870 [2.387]	-0.091 [0.913]	0.405 [1.500]									
Q10. Trap Neuter Return (where **feral cats are captured, neutered, and released back into the wild)**														
✓	✓	✓	✓		✓	✕	✕	✕	✕	✕	✓	✓	✓	✓
SA	0.292 [1.339]	**2.293 [9.900]**	**-0.316 [0.729]**		0.325 [1.384]									
A	**1.050 [2.859]**	**0.895 [2.448]**	**0.462 [1.587]**		**0.816 [2.262]**									
N	**1.523 [4.586]**	**2.981 [1.678]**	**0.517 [1.678]**		0.213 [1.237]									

D	**2.060 [7.847]**	3.372 [3.260]	**1.182 [0.729]**		1.335 [3.807]									

6.4.2 Management decision options

All the best models for the management questions contained cat ownership, country of birth, country of residence and the interaction between country of birth and residence, except for the acceptance for TNR which did not include the interaction. Apart from the questions relating to cats wearing anti-predation gadgets and euthanizing feral cats is not acceptable, either age or employment status or both were also found to be significant factors in the models (Table 6.2B).

For the management opinion that no one in town should own a cat, UKUK are significantly more likely to strongly agree or agree than strongly disagree (OR 6.53 and OR 9.72 respectively) while those that have moved to Nigeria (UKN) are significantly less likely to strongly agree or agree than strongly disagree (OR 0.25 and OR 0.27 respectively) and are significantly more likely to be neutral than strongly disagree (OR 4.62). NN are more likely to be neutral or disagree than strongly disagree (OR 1.96 and 4.06 respectively) but NUK are significantly more likely to agree or be neutral (OR 2.30 and OR 5.52) than strongly disagree that no one in town should own a cat (Figure 6.M1; Table 6.2B), therefore both immigrants become less opinionated.

Nigerian residents are significantly more likely to strongly agree or agree than strongly disagree (OR 2.68 and OR 4.61 respectively) that people in eco-sensitive areas should not own cats, with the UK nationals supporting the statement even more (OR 11.24 and OR 12.10; Figure 6.M2; Table 6.2B). Although NUK and UKN are significantly more likely to strongly agree (OR 1.31) and agree (OR 1.17) than strongly disagree respectively, it is to a lesser degree than their residential counterparts (Figure 6.M2; Table 6.2B).

For the management opinion that all cats should wear collar bells / anti-predation gadgets, UK nationals irrespective of where they are living, are significantly more likely to strongly agree than strongly disagree (UK OR 7.96; N OR 47.90). NN are significantly more likely to strongly agree than strongly disagree (OR 2.23) but to a lesser extent than UK nationals. Although NUK strongly agree it was not found to be significantly more than strongly disagree (Figure 6.M3; Table 6.2B).

NN are significantly more likely to agree than strongly disagree (OR 2.68) that cats should not be permitted out during the day although UKUK were even more likely to agree than strongly disagree (OR 6.32). However NUK were not significantly more likely to agree or strongly agree and UKN are significantly more neutral than strongly disagree (OR 10.74) that cats should not go out during the day (Figure 6.M4; Table 6.2B).

NN are significantly more likely agree than strongly disagree (OR 2.33) that cats should not be permitted out during the night and the same applies for NUK but to a lesser degree (OR 1.28). Although UKUK are more likely to strongly agree or agree than strongly disagree it was not significant, however UKN are significantly more likely to strongly agree or be neutral than strongly disagree (OR 11.56 and 20.72 respectively; Figure 6.M5; Table 6.2B).

On the management opinion that cats should be registered with the local government council. Nigerian nationals irrespective of place of living are significantly more likely to strongly agree (NN OR 46.24; NUK OR 10.21) or agree than strongly disagree (NN OR 130.65; NUK OR 16.30), although NUK showed a reduced chance for both indicating a shift to disagreeing with the statement. UK nationals are also significantly more likely to strongly agree (UKUK OR 22.63; UKN OR 1.40E+7) or agree (UKUK OR 30.29; UKN OR 1.36E+7) than strongly disagree that cats should be registered with the local government council (Figure 6.M6; Table 6.2B).

NN are significantly more likely to strongly agree or agree than strongly disagree (OR 20.48 and OR 51.21 respectively) that cats should be neutered. Although NUK are significantly more likely to strongly agree or agree than strongly disagree (OR 1.52 and OR 4.06 respectively), it is to a lesser degree and shows some strongly disagreeing to cats being neutered. For UK nationals, although UKUK strongly agree or agree than strongly disagree that cats should be neutered it is not significant, however UKN are significantly more likely to strongly agree than strongly disagree (OR 112.59; Figure 6.M7; Table 6.2B).

On the management opinion that more effective management of cats is needed, NN are significantly more likely to strongly agree or agree than strongly disagree (OR 23.41 and OR 61.43), again although NUK are significantly more likely to strongly agree or agree than strongly disagree (OR 8.37 and 20.54 respectively), the responses show some strong disagreement to the statement (Figure 6.M8; Table 6.2B). UKUK are more likely to strongly agree or agree than strongly disagree, although it is not significant, however UKN are significantly more likely to strongly agree than strongly disagree (OR 225.97) with no disagreement to the statement (Figure 6.M8; Table 6.2B).

The management opinion that euthanizing feral cats is not acceptable have NN significantly more likely to strongly agree or agree than strongly disagree (OR 4.04 and OR 8.82 respectively) although NUK did not show a significant difference from strongly disagree (Figure 6.M9; Table 6.2B). UKUK are significantly more likely to be neutral than strongly disagree (OR 3.58) that euthanizing feral cats is not acceptable and UKN are significantly less likely to strongly agree and even more likely to be neutral than strongly disagree (OR 0.78 and OR 15.86 respectively) showing the shift to a neutral probability overwhelming (Figure 6.M9; Table 6.2B).

NN are significantly more likely to agree than strongly disagree (OR 2.86) to the Trap Neuter Return (TNR) programme and NUK are also significantly more likely to agree than strongly disagree (OR 1.59) although to a lesser extent, with more indicating they strongly disagree. UKN are significantly more likely to strongly agree or agree than strongly disagree though (OR 9.90 and OR 2.45 respectively) but UKUK were not found to be significant in the model (Figure 6.M10; Table 6.2B).

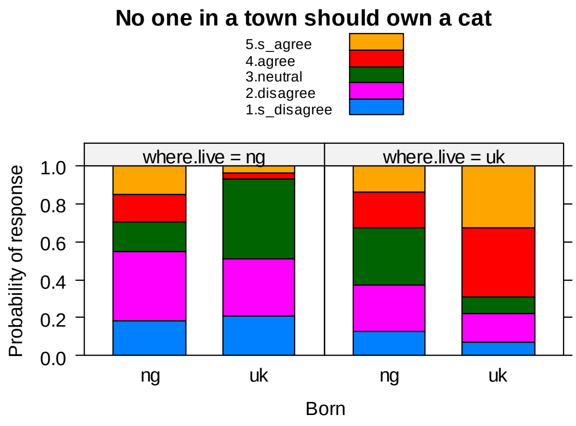

Figure 6.M1

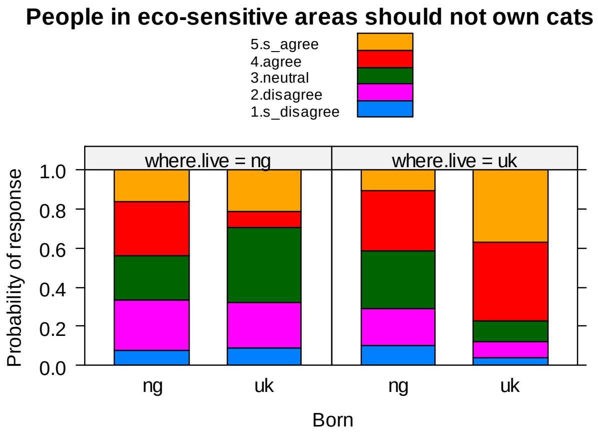

Figure 6.M2

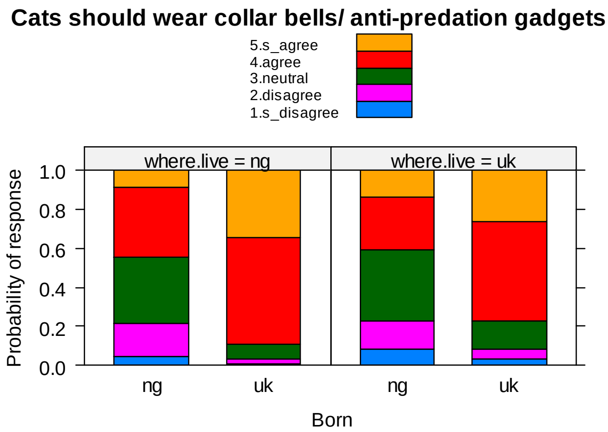

Figure 6.M3

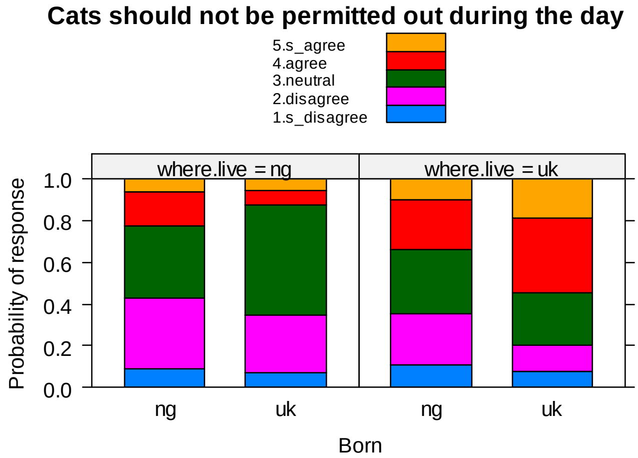

Figure 6.M4

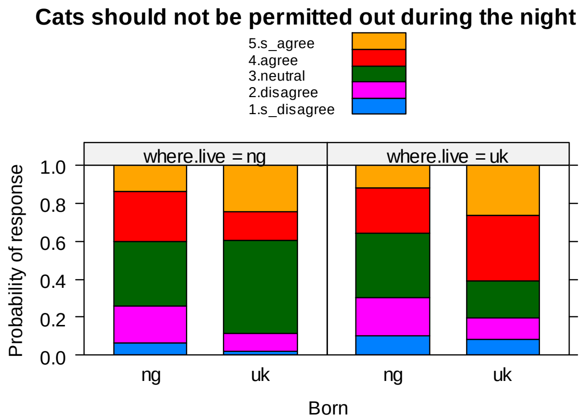

Figure 6.M5

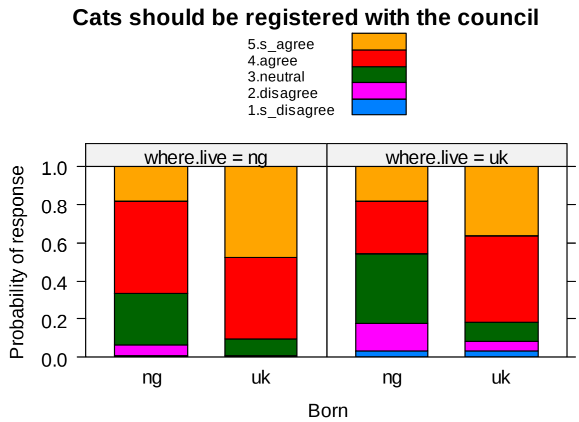

Figure 6.M6

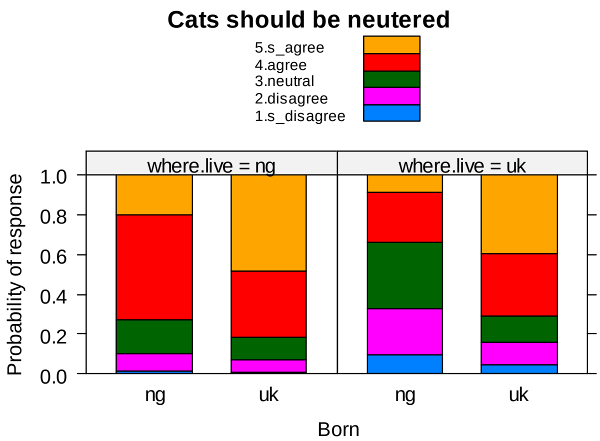

Figure 6.M7

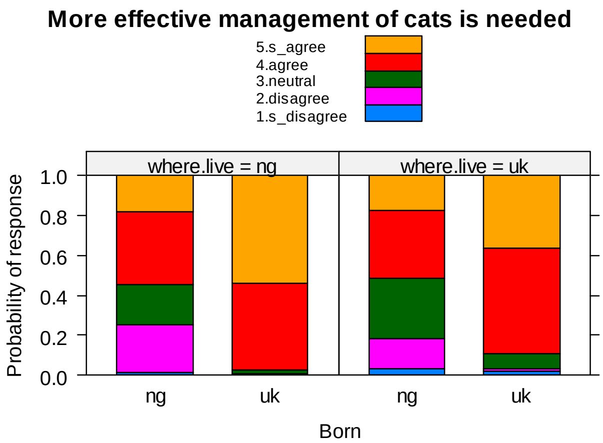

Figure 6.M8

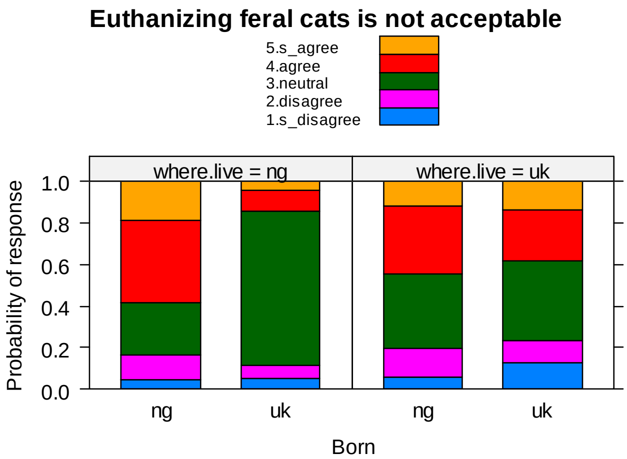

Figure 6.M9

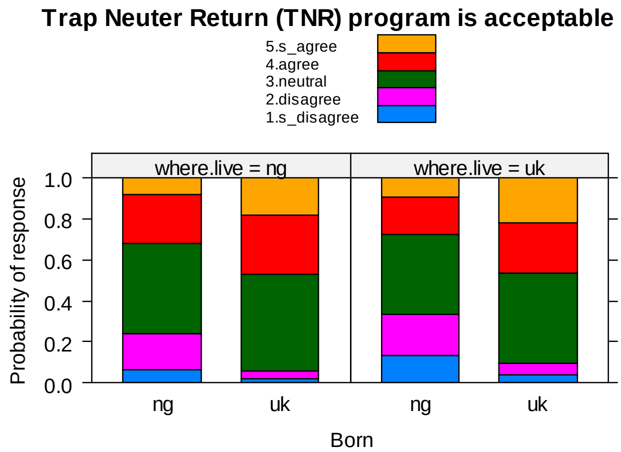

Figure 6.M10

Figures M1 to M10: Modelled probabilities for each response (strongly agree (SA), agree (A), neutral (N), disagree (D), strongly disagree (SD)) to each statement by the four different categories of nationality and country of residence (NG = Nigerian / Nigeria, UK = British / UK).

6.5 Discussion

6.5.1 People's attitude towards cats and predation

We find considerable differences in attitudes towards cats between people from Nigeria and people from the UK. Not only this, but these effects are not completely lost when people move from one country to another; we can see how some attitudes shift depending newly shared cultures. To our knowledge, there is no study which shows so clearly how plastic attitudes can be as people lived experience changes.

Spiritual reasons were the most important reason for NN not owning cats. It is strongly believe that cats can be spiritually possessed and use for negative purposes in witchcraft (Bukar-Kolo et al. 2018). Very few UKUK gave spiritual reasons as a factor for not owning a cat, while NUK are lower than NN, and UKN is higher than UKUK. People born in Nigeria are inclined to strongly agree that feral cats have the right live in their neighbourhood regardless of which country they live in, but people born in the UK who move to Nigeria disagree more than those who stay in the UK, indicative of the effects of changing country of abode and perhaps increased exposure to feral cats (Chapter 3). The same can be argued for the response on the attitude question on acceptability of eating cat in which the probability to strongly agree decrease and the corresponding likelihood of disagreeing for NUK compared to NN (Figure 6.A5) is seen to reflect the shift in attitude due to changing countries, evidence of influence due to long term interaction with the UK culture and experience but the same is not the case for UK nationals who moved to settle in Nigeria, where eating cat is considered unacceptable.

For some issues only country of residence matters, as is the case for the attitude question on 'I feel feral cats are a nuisance', people living in Nigeria regardless of where they were born are significantly more likely to strongly agree while people living in the UK (UKUK and NUK) regardless of where they were born are seen to be more spread in their responses with some level of disagreement (Figure 6.A3). Similarly, the attitude statements on 'Free roaming cats harm wildlife' and 'Cats control pests in my locality', where it is seen that people living in Nigeria appear to strongly agree with both statements regardless of where they were born, with high probability for strongly agree for UKN agreeing with the NN position but against the UKUK result, where there is low probability of strong agreement with these statements (Figure 6.A4). Agreement with the statement that 'Cats are associated with witchcraft' is also aligned with country of residence rather than country of origin.

Respondents born in NG and now living in UK are seen to differ in opinion with the original strongly agree position of NN respondents, and similar results are found in the reverse direction. In contrast results indicate that migrants (NUK and UKN) are less likely to agree with the very positive opinion of NN and UKUK that cats make good pets suggesting that migrant status may also affect some attitudes. Overall UK nationals irrespective of where they live are less likely to agree overall that 'Feral cats have the right to live in my neighbourhood', 'it is acceptable to eat cats', and 'cats are associated with witchcraft'.

6.5.2 Management decision options

Our survey demonstrated strong public agreement in all cases that all cats should wear collar bells or any other anti-predation gadgets as the most highly recommended option for potential management of cat's predation. Other studies (Nelson et al. 2005; Gordon et al. 2010; Thomas et al. 2012) have highlighted these as effective strategies to reduce cat predation (Van-Heezik et al. 2010). The management option that cats should be registered enjoyed overwhelming acceptability with all NN, NUK, UKN and UKUK respondents. This is in line with international levels of support recorded in other studies at other geographic locations (Lilith et al. 2006). Acceptability of option that cats should be registered among the cat owners was weaker for NN, and non-cat owners were more supportive of this management option. This observation is in agreement with the experience in Australia, where mandatory registration of cats with Councils is already in effect (Lilith et al. 2006). Overall, respondents also supported neutering as a means of managing domestic cat populations. These range of support and higher levels have also been reported in other studies internationally, 86% in Singapore (Gunaseelan et al. 2013), 88–93% in Australia (Perry 1999, Lilith et al. 2006), 93% in New Zealand studies (New Zealand 2016; Hall et al. 2016), and lower values of 58% New Zealand (Walker et al. 2017), and 60.9% Reading, UK (Thomas et al. 2012).

In comparing the residential locations responses on the management options it is evidence that broad groupings emerge that broadly captures typical responses. UK nationals irrespective of where they live are significantly more likely than Nigerian nationals to strongly agree with the management opinions/statements that cats should wear bells or any other anti-predation gadgets, cats should be registered with the Council, cats should be neutered, that more effective management of cats is needed and that Trap Neuter Return (TNR) is acceptable

Other groups are those whose attitudes change with migration (i.e. UKUK vs UKN and NN vs NUK), or where changing country matters, but only for one country group and with the born and live variables are significant too (e.g. no difference between NN and NUK, but there is a difference between UKUK and UKN). The decrease in probability for strongly agree and agree position of UKN and the corresponding increase in the strongly disagree and disagree probability compared to the original UKUK case is seen for the management options that no one in a town should be permitted to own a cat, people in eco-sensitive areas should not own cats and cats should be put on a day and night curfew (Figures M1, M2, M4 and M5). People born in the UK who move to Nigeria (UKN) are significantly less likely to strongly agree more than those who stay in the UK and the same is not the case for people born in Nigeria (NN vs NUK). On the management option that feral cats are trapped neutered and released back into the wild, this study shows that in all the cases the respondent's leans towards being neutral on this management option. This UK national's position on this option has earlier been captured by Thomas et al. (2012).

Depending on some underlying factors which includes policies, pervasiveness of beliefs and inherent cultures, public enlightenment and proactive engagement approaches, results thus so far show that long term interactions with a different culture and experience resulting from migration between countries and cultures can affect some aspects of peoples' attitudes and feelings to significant conservation questions of cat predation and resultant management options.

6.5 Conclusion

The importance of understanding of the prevalence and diversity of different attitudes towards cats and their control across the world cannot be over emphasized. The alternative is that the culturally dominant views of those living in the few countries where such questions are asked, such as the UK, USA and Australia, are taken as the norm and imposed elsewhere. This study attempts to understand how cultural differences may result in differing attitudes towards cats and their position towards management options for resident's locations in Nigeria and the UK. Furthermore, people's views are not fixed. Experience and the surrounding, dominant, culture will affect views. We explore this for the first time from a conservation perspective, and overall this study confirms that long term interactions with new cultures and experiences resulting from migration between countries can affect some aspects of people's attitudes and feelings to cat predation and management options.

While there are differences (particularly with regards the acceptability of eating cats or the role of cats in witchcraft), attitudes which focus on cats as predators, and options for mitigating these are positive in both countries. Nigerians living in Nigeria strongly support the following options for managing domestic owned cats and feral cat populations and predation: (1) People in eco-sensitive areas should not own cats, (2) All cat to wear collar bells/anti-predation gadgets, (3) Cats be registered with the local Council, (4) Cats should be neutered, (5) Feral cats be protected and managed as wildlife. Nigerian nationals in the UK, and UK nationals at home and in Nigeria also supported the above options, except for the option that people in eco-sensitive areas should not own cats. Together, these can help form the basis of approaches to managing cats in regions where cats are a clear danger to wildlife.

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6.7 Appendixes

Appendix 6.7.1: Tables

Table 6.3. Percentage distribution of respondents reasons for not owning cats (all residential locations)

Reasons for not owning cats.					
Nigerians resident in Nigeria		%	Nigerians residents in UK		%
Cat kill small animals	43	7.66	Cat kill small animals	4	1.7
Cats are expensive to keep	11	1.96	Cats are expensive to keep	24	10.3
Cats carry diseases	127	22.64	Cats carry diseases	16	6.8
Inhumane to keep cats	16	2.85	Inhumane to keep cats	30	12.8
No space to keep cats	60	10.70	No space to keep cats	67	28.6
Spiritual reasons/can easily be possessed	245	43.67	Spiritual reasons/can easily be possessed	36	15.4
Other reasons	59	10.52	Other reasons	57	24.4
UK residents in Nigeria		%	UK residents in UK		%
Cat kill small animals	4	1.7	Cat kill small animals	8	3.2
Cats are expensive to keep	24	10.3	Cats are expensive to keep	40	15.9
Cats carry diseases	16	6.8	Cats carry diseases	7	2.8
Inhumane to keep cats	30	12.8	Inhumane to keep cats	13	5.2
No space to keep cats	67	28.6	No space to keep cats	27	10.8
Spiritual reasons/can easily be possessed	36	15.4	Spiritual reasons/can easily be possessed	6	2.4
Other reasons	57	24.4	Other reasons	150	59.8

Chapter 7. Discussion

7.1 Cat predation

Domestic cats (*Felis catus*) have long lived in close association with humans (Driscoll et al. 2007, Morling 2014). It is only recently that the role of predation by domestic cats in the decline of biodiversity, or extinction in some cases, and possible management responses is now a topical issue. Nevertheless, very few full scale studies of predation by urban domestic cats have been done, and then only in a few countries, including Australia (Barrat 1998; Morgan et al. 2009), the UK (Baker et al. 2008; Thomas et al. 2012; Pirie et al. 2022), New Zealand (van Heezik et al.2010) and now Nigeria (Chapter 3, 4 & 5). Cat density per km^2 based on line transect detection taken during the day (which is likely be an underestimate) gave an estimate of 224.70 cats per km^2 (95% CI 195.7 - 293.7) for Lagos and falls within the lower ranges of studies in other urban settings, with recorded cat densities of 229 cats/km^2 (Baker et al. 2005; Bristol, UK); 2300-2800 cats/km^2 (Mirmovitch 1995; Jerusalem, Israel); 132-1580 cats/km^2 (Sims et al. 2008; Britain); 248-445 cats/km^2 (Thomas et al. 2012; Reading, UK). Our house-to-house survey shows that rates of pet cat ownership in Lagos is relatively low, with less than 3% of households owning cats, which contrasts with typical rates of cat ownership of around 25% of households found in Europe, North America and Australia (Sims et al. 2008; Thomas et al. 2012; Murray et al. 2010; Toribio et al. 2009).

While estimates of cat density was lower than perhaps expected (and I return to this later), home range size was similar to that found in other studies, suggesting a common behavioural response in very different locations.

This study investigated what factors affected total prey returns, and for mammal, bird and reptile returns in urban Lagos. I found that cats returned substantial amount of prey across all four study sites with prey types similar to those recorded in other studies. Mammals were the most frequently recorded prey captured by cats in Lagos and were followed by birds, reptiles and amphibians in rank order of prey abundance (Liberg, 1984; Weber & Daily, 1998; Biró et al., 2005; Campos et al., 2007; Krauze-Gryz et al 2012; Thomas et al. 2012). In this study the numbers of prey brought home were affected by the season as more prey were brought home by cats during the dry season, and for both the dry and wet seasons male cats were significantly more likely to return prey compared to females.

I find that pet cats in Lagos have similar home ranges to cats elsewhere, and are at densities towards the lower end of previously published studies, but domestic cats are likely to kill substantial numbers of prey, including in the region of 100 million vertebrates killed by owned cats in one single city alone

(Chapter 5). Given that feral cats are also abundant, domestic cats are likely to be a significant cause of mortality of small and mid-sized terrestrial vertebrates in West Africa.

7.2 Nigerian attitudes towards cats, predation and management.

Estimates of wildlife mortality credited to feral and domestic cats is projected in very high ranges, with predation on bird populations perhaps being considered more contentious and controversial (Peterson et al. 2012). Understanding of public awareness of these predatory impact of cats is limited to countries such as the UK, USA, and Australia and views reflected in these countries have inherent local content as attitudes of people towards cats (and indeed any issue of conservation concern) can differ with culture. Using a questionnaire I examined how people in Nigeria view pet and feral cats, whether they see predation as an issue. I find effects of culture and deep-rooted myths, with negative views of cats as being associated with witches and wizards, and the issue of high cat mortality due to the acceptability of eating cat meat. This study reveals a high percentage in agreement that pet cats and feral cats live healthy and happy lives stood at 100% and 67% respectively and Nigerians perceptions of cats is found to be somewhat biased against feral cats as most respondents do not believe that the domestic cats do much harm to wildlife and majority feels that free roaming and feral cats are more likely to harm wildlife and similar lower levels of concern regarding domestic cat predation have been reported in other studies (Lilith et al. 2006; Thomas et al. 2012; Walker et al. 2017).

Results from this study shows that acceptable management options are comparable to other studies in other geographic locations and includes suggestions that cats should wear collar bells or any other anti-predation gadgets that cats should be registered, strong support for neutering, and that people in eco-sensitive areas should not own cats. Overall more than 77% agreed with non-lethal management options to reduce rates of cat predation, particularly near areas of conservation value.

7.3 Urban cat population density in Nigeria

Reliable cat population density estimates are essential in managing cat populations (Schmidt et al 2007; Thomas et al. 2014; Elizondo and Loss 2016). Densities of cat recorded in studies are in the range of 229-523 cats/km^2 (Baker et al. 2008; Thomas et al. 2012; Loss et al. 2013) in the UK and USA and 105-244 cats/km.in (Chapter 3) in Lagos Nigeria. Our study finds that the cat population estimate for Lagos (1171 km^2) is in the order of 122,143 – 286,538 cats.

Studies from our house-to-house survey reveals that rates of pet cat ownership in Lagos are relatively low, with fewer than 3% of households owning cats, which contrasts with typical rates of cat ownership of around 25% of households found in Europe, North America and Australia (Sims et al. 2008; Thomas et al. 2012; Murray et al. 2010; Toribio et al. 2009). Furthermore, there was a low number of neutered cats (1%) in this study, which is perhaps the lowest recorded in studies that examine cat demographics, were we have values as high as 97.3% in Sidney, Australia (Toribio et al. 2009); 96% in Reading, UK (Thomas et al. 2012); 70.5% Central Italy (Carvelli et al. 2016); and 45% in Italy (Slater et al. 2008). This low level practice of neutering might be due to the absence of any national policy toward containment of cat population management in Nigeria, the cost and lack of veterinary care, and the overwhelming lack of information and awareness on the part of the populace of the predatory impact of cats.

7.4 Ranging pattern of pet cats.

Understanding the ranging characteristics of individual cats is critical when trying to understand their impact on biodiversity (Thomas et al. 2014; Dickman and Newsome 2015; Hanmer et al. 2017), as understanding where they hunt provides insights into prey at risk and possible predation management. In this study the absolute mean maximum daily area ranged by a cat was 13.18 ha, an equivalent of 230 m diameter for a circular area and a radius of 115m. The seasonal home range inclusive of both the wet and dry season from 0.07 ha to 10.40 ha at 95% KDE for all cats recorded in our study reflect findings of other research efforts with values ranging from 0.04-228 ha (Warner 1985; Horn et al. 2011; Thomas et al. 2014; Kitts-Morgan et al 2015; Kays et al. 2020; Pirie et al. 2022).

Our results suggest that cats range further in the night than in the day, and this outcome is similar to the results of most other studies (Barratt 1997a; Metsers et al. 2010; Thomas et al 2014). This will provide another lead to effective management of cat predation if restriction of cat movement in the night is adhered to by cat owners.

Cats with larger home ranges could potentially inflict more damage on wildlife and our study demonstrates buffer zones in the order of >300 meters would be effective in safeguarding important wildlife habitats in tropical habitats, just as much as in other parts of the world.

7.5 Prey returns and predation rate

Cats kills large numbers of prey; they are the primary threat to over 8% of threatened reptiles, birds, and mammals (Medina et al. 2011; Doherty et al. 2016) and are the most abundant predator in many urban ecosystems (Liberg et al. 2000; Loss et al. 2013; Thomas et al. 2012; Hanmer et al. 2017). Studies show prey type and opportunities differ extensively with geographical and ecological regions (Kitts-Morgan et al. 2015; Pirie et al. 2022). The wide range in variation amongst studies in the proportion of prey returned home from other predation studies 50% (George, 1974), or 30% (Kays and DeWan,

2004) to 12.5% (Maclean, 2007) reflects the variation in the conversion factor which differs from study to study, and is affected by the cats themselves, and the nature of prey available. This study have taken a conservative approach and adopted the highest percentage quoted for prey return home from a radio-tracked cats' direct observation and collar mounted cameras sources which is 30% and hence overall mortality is estimated using a 3.3 prey return conversion factor (Kays and DeWan, 2004). The mean daily return rates for the seasons are 0.40 ± 0.034 (mean ± SE) for the dry season and 0.32 ± 0.038 for the wet season with a calculated mean annual predation rate of 412 prey per cat per year. This is high compared to previous studies, which typically range from 14 to 302 prey per cat per year depending on location, suggesting that the higher levels of prey availability, perhaps combined with locally low rates of food provision for owned cats, results in high predation rates.

Prey types are similar to those recorded in other studies, with mammals the most frequently returned prey, followed by birds, reptiles and invertebrates in that order (Churcher & Lawton, 1987 Tschanz et al., 2010., Thomas et al. 2012; Loyd et al., 2013; Pirie et al. 2022). There were significantly higher mammal and bird return rates per day in the dry season. The sex of the hunting cat did significantly affect the total mean daily rate of prey return, as male cats were significantly more likely to return prey than females.

Our study found that cats carrying GPS trackers, for both dry and wet seasons, were significantly less likely to return prey than cats that were not tracked. This suggests that studies where cats are wearing collars (whether with GPS units, or anti-predation devices) would have significantly reduced predation rates.

7.6 Influence of life experience on attitude to conservation and domestic cat welfare.

Cats are now one of the world's most common pets with popularity for companionship vastly increasing in many countries. Feral cats and free-roaming domestic cats are recognised as one of the world's major threats to biodiversity. Our study was to explore how residents' perceptions of and attitudes towards domestic cats and feral cats differ between countries and cultures and if responses are likely to be affected by long term interaction with foreign culture and experience resulting from long term migration. To our knowledge, there is no study which shows so clearly how plastic attitudes can be as people lived experience changes.

We find considerable differences in attitudes towards cats between people from Nigeria and people from the UK. Not only this, but these effects are not completely lost when people move from one country to another as is the case for the attitude question on 'I feel feral cats are a nuisance', people living in Nigeria regardless of where they were born are significantly more likely to strongly agree, while people living in the UK regardless of where they were born are seen to be more spread in their responses with some level of disagreement. UK nationals irrespective of where they live are less likely to agree overall with the statements that 'Feral cats have the right to live in my neighbourhood', 'it is acceptable to eat cats', and 'cats are associated with witchcraft'.

When considering management options, it is evident that broad groupings emerge that broadly capture typical responses. UK nationals irrespective of where they live are significantly more likely than Nigerian nationals to strongly agree with the management opinions/statements that cats should wear bells or any other anti-predation gadgets, cats should be registered with the Council, cats should be neutered, that more effective management of cats is needed and that Trap Neuter Return (TNR) is acceptable.

It is evident when we consider the two survey chapters together that Nigerians have an interesting duality in attitudes towards cats, and that some of these attitudes can change as lived experience changes. Pet cats are considered with affection, and feral cats so to a lesser extent, but we find effects of culture and deep-rooted myths, with negative views of cats as being associated with witches and wizards, and the issue of high cat mortality due to the acceptability of eating cat meat (chapter 2). Nevertheless, Nigerians strongly support the following options for managing the populations and predation of domestic owned cats and feral cats: (1) People in eco-sensitive areas should not own cats, (2) All cat to wear collar bells/ anti-predation gadgets, (3) Cats be registered with the local council, (4) Cats should be neutered, (5) Feral cats be protected and managed as wildlife.

This study included residents living in areas within a reasonable distance of the Lekki Conservation centre, a large biodiversity conservation park in the centre of the Lekki stretch in Lagos, Nigeria. Here predation potential is heightened by a greater likelihood of cat–wildlife interactions, and so study findings are expected to have great relevance for active management of threats from cats to species of conservation concern.

7.7 Further work

While this work provides the first insights into both cat behaviour and demographics, and the attitudes of the people living around and with them, it is clear that there is so much more that could be done. One key consideration is whether predation estimates can be improved. Results of studies assessing predation using collar mounted cameras sources have offer a more reliable measure of cat activities and predation than observation or scat analysis (Loyd et al., 2013; Morling 2014; McGregor et al., 2015; Huck and Watson, 2019; Seymour et al., 2020) and hence future research efforts should deploy animal-mounted video systems so that ambiguities associated with free ranging domestic cat behaviour could be adequately quantified. Furthermore, it is not clear how representative Lagos is of the region. Do those living elsewhere consider cats in similar ways? Do local conservationists see cats as an issue, or are they a minor threat compared to great threats resulting from habitat loss as the megacity expands? The focus of conservation work in the global north, funded by and conducted by organisations and individuals from such backgrounds means that local perspectives are lost. More than that, for the first time we explore how migration affects attitudes and helps us begin to think about how new ideas and understandings can flow across distant borders.

Nigeria is a very large, highly populated, and ethnically diverse country. While this work is the first to gain insights into a key issue of urban conservation concern, work is required to uncover likely considerable differences in attitudes across the country, between ethnic and socioeconomic groups, and how these differences in attitudes are expressed in terms of both the welfare of cats, and the challenges for conservation that emerge from their presence.

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