Report

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A literature review on the effects of pet cats on nearby protected wildlife sites

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Summary

This report, commissioned by Breckland Council and Natural England, provides a summary of the current evidence available relating to the potential impacts of domestic cats on wildlife in the United Kingdom and the links between development and cat predation on nearby wildlife sites.

Cats are a popular and valuable companion animal in the UK and studies suggest that the population of owned cats in the UK exceeds 10 million. Approximately one quarter of households in the UK own at least one cat and various factors, such as income, region, education level and gender appear to influence levels of cat ownership.

The domestic cat *Felis catus* is a highly successful generalist predator and has become one the most abundant carnivores in the UK, reaching far higher densities than native carnivores, such as the red fox. It is primarily a predator of small mammals, but will also kill large numbers of birds, herpetofauna and invertebrates. Whether or not predation by cats has a significant impact on prey populations depends somewhat on whether cat-induced mortality is compensatory (i.e. the animal would have died anyway) or additive (i.e. the death of the animal is a loss to the population) and requires a detailed understanding of the population dynamics of the prey species.

The home ranges of cats have been studied worldwide and mean hunting ranges of in excess of 300 hectares have been recorded; males have been observed to have consistently larger home ranges than females, and nocturnal home ranges are larger than diurnal ones. When considering the maximum linear distance travelled by cats from one point to another, distances of over 3km have been recorded.

Measures to mitigate the effects of cat predation have been studied, including the use of bells and other collar-mounted devices along with fencing and the modification of cat behaviour by owners, such as limiting the amount of time a cat spends outside. To date, no method has entirely prevented predatory activity in cats, but many have reduced predation rates of certain groups of species.

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1. Introduction & Methods

1.1 The domestic cat has been a highly valued human companion, since it's domestication from ancestral wildcat species, the European and African wildcat (*Felis silvestris* and *Felis libyca)* several thousand years ago. Cats were first domesticated in ancient Egypt in order to control pests of grain stores, such as rodents and snakes; they spread gradually across Europe, finally reaching the UK after introduction by the Romans. It is now one of the most numerous non-native mammals in the United Kingdom.

1.2 While cat ownership may have benefits for human wellbeing such as companionship, along with functional benefits, such as rodent control, there are concerns over the potential impact of cats on wildlife populations globally, most notably on oceanic islands.

1.3 As urbanisation increases in the UK and globally, an increase in populations of some companion animals, such as domestic cats is to be expected. This may have consequences for the nature conservation interest of areas adjacent to urban areas. This is therefore of relevance to planning bodies permitting new development in close proximity to areas of wildlife interest, who should seek to ensure that new development does not harm biodiversity. With increasing pressure for development in the UK, it is therefore important to gain an understanding of the ecological impacts that increasing numbers of domestic cats could have. This report has therefore been commissioned to summarise existing information relating to the links between cats and urban development, collating evidence to inform spatial planning in terms of both plan making and managing development proposals.

1.4 The review draws from literature on both domestic and feral cats in the UK, Europe, USA, Australia and New Zealand. Relevant studies primarily been identified from previous reviews (Underhill-Day 2005), the Footprint Ecology in-house reference database and on-line searches using standard search engines. The key search terms used to identify relevant literature were as follows:

- 'domestic cat', 'ownership', 'ownership UK', 'legal'
- 'domestic cat','home range', 'hunting'
- 'feral cat','home range', 'hunting'
- 'cat', 'predation', 'domestic cat, wildlife'
- 'cat','predation', 'mitigation', 'bells', 'predator fencing'

1.5 Other on-line searches were made to obtain specific information, including websites of the RSPB, Cats Protection League and RSPCA.

2. Cat numbers and ownership in the UK

2.1 The domestic cat *Felis catus* is the most abundant carnivore in Great Britain, with populations estimated to be in excess of 9 million in 2003, including a feral population of at least 800,000 (Woods, McDonald, & Harris 2003). A more recent study provided a reliable baseline estimate of the number of owned cats in the UK at over 10.3 million in 2006 (Murray *et al.* 2010); this did not take into account any estimates of non-owned cat (feral or stray) populations. Cat densities, recorded in a study into urban bird predation, by far exceed those for any other carnivore found in Great Britain, with a calculated density of 229-523 cats/km² (Baker *et al.* 2008). Studies also indicate that the domestic cat is adapting its use of territory to accommodate increasing densities, such as territory sharing in 'shifts' with neighbouring cats taking turns to be outdoors or in the home.[1] Comparably, the densities calculated for the Red Fox *Vulpes vulpes* and Eurasian Badger *Meles meles* were 37/ km² and 7.5/ km² respectively. Sims (2008) estimated cat densities in their study areas as between 132 and 1580 cats/km².

2.2 The work by Murray (2010) provides an insight into some of the key characteristics of cat owning households in the UK in 2007. Some 26% of those households sampled owned at least one cat, with the majority of those households having only one (58.3%). Some 29.3% owned two cats, 7.2% three, 2.1% 4, 1.4% five and 1.6% between six and twelve cats. Other ownership patterns were identified, finding, for example, that cats were more likely to be owned in households with gardens (97.6%) and more often by females (70%). Households were more likely to own a cat in rural or semi-urban areas, perhaps reflecting the assumption that cats are more likely to be at risk from accidents in more urbanised areas.

2.3 Patterns of ownership differ somewhat between regions of the UK, with 30% of households in the south west owning at least one cat, compared to only 10% in the West Midlands (Saul 2000). Saul also suggested that other factors, such as household income, can influence cat ownership, with an increasing likelihood of cat ownership as annual income rises. Although the reasoning remains unclear, Murray (2010) found that the education level of household members was associated with cat ownership; households containing members who had gained a university degree were 1.36 times more likely to own a cat than those households containing members without a degree.

2.4 While domestic cats and dogs may be legally regarded as 'property' in the UK (Cats Protection League 2009), cat ownership has not been subject to some of the controls imposed on dog owners in many countries. For example in the UK, dog owners were subject to licensing until 1987.

[1] BBC2 Horizon Programme 12. "The Secret Life of the Cat" broadcast June 2013.

3. Cat behaviour and prey composition

3.1 Cats are generalist predators which hunt opportunistically and instinctively, while typically receiving food from humans. The degree to which cats rely on humans for food and shelter varies greatly; from those that are totally non-reliant on humans, being feral or semi-feral, to those that are companion animals (Baker *et al.* 2008). Owned cats depend on food supplied by their owners and therefore the availability of wild prey does not act to limit their populations (Woods, McDonald, & Harris 2003).

3.2 Domestic cats are successful predators, and rely on visual cues along with excellent acoustic discrimination abilities in order to search for prey (Turner & Bateson 2000). Adult cats are able to kill prey swiftly and efficiently, normally by constriction between the head and body with strong jaws. Cats are typically predators of small mammals and birds and will generally catch prey no larger than themselves; cats are typically not strong enough to kill a healthy adult rabbit, but may take young or weaker animals. Cats will also kill invertebrates, fish and herpetofauna. As a result of this proficiency as a predator both in the UK and worldwide, cats have the potential to cause major ecological impacts. Table 1 provides a summary of cat prey composition based on six studies.

Table 1: The proportions of different prey types recorded in six studies. The percentage of each prey type of the total for each study is given in parentheses.

Source	Location	Mammals	Birds	Herps/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)	

3.3 A study carried out by Woods and others (2003) on behalf of the Mammal Society investigated the number of prey items brought in by domestic cats on a national scale, with prey records obtained from 618 households. Variation between individual cats was high, with younger and thinner cats of both sexes, on average, returning more birds and herpetofauna than older, fatter cats. Those cats that wore bells or were kept indoors overnight brought home fewer mammals, through the limitation on a cats ability to hunt primarily nocturnal prey species at night. Predatory activity is thought to decline after approximately six years of age (Hansen 2010).

3.4 Using figures presented in Woods (2003) and Howes (2000) Underhill-Day calculated that the mean annual catch per cat was 29 prey items. Taking 320 as the estimated number of cats per 1000 households from Woods and other, this would give a figure of

9261 prey items per annum per 1000 households. However this calculation was conservative as it did not account for prey items not brought home.

3.5 While many studies have relied on cat owners to record prey items returned home by cats due to their apparent predisposition to bring prey items back to their owners' residence, a recent study in the USA used animal-borne video cameras to record predation by 55 domestic cats (Loyd *et al.* 2013). Each cat in the study wore a camera for 7 to 10 days and all activity during that time was recorded. On average, 2.4 prey items were captured during seven days of roaming; 23% of prey items were returned home, 49% were left at the site of capture and 28% were eaten. The results suggest that previous studies may have significantly underestimated the capture rates of domestic cats.

3.6 The amount of time spent hunting and the success of hunting varies greatly between individual cats, with some cats being proficient and prolific hunters and others catching nothing. Barratt (1998) recorded that the number of prey brought home by cats ranged from 0 to 72 items per cat. Tschanz (2011) confirmed that variation between individuals is very high in relation to hunting activity in Switzerland; finding that 16% of cats accounted for 75% of prey items brought home.

3.7 There is evidence of cats predating key species associated with the Breckland Special Protection Area (SPA). Of 147 woodlark nests monitored with cameras in a study by Dolman *et al.* (2010), 47 different nests were predated and one of these nests was predated by a cat. Studies outside the UK also indicate that cats may predate stone curlews (Tjorve 2006; Millan 2010).

3.8 With the possibility that cats are adapting to higher cat densities by sharing territory in shifts, there is further intensification of hunting within each territory. Time spent hunting in any given 24 hour period is potentially doubled when two cats sharing the same territory are working in 'shifts' with each spending time indoors whilst the other is out.

4. The impacts of predation on wildlife

Overview

4.1 There is a widespread belief that domestic cats kill large numbers of wild birds, mammals and reptiles, with the potential to greatly influence prey population dynamics; directly, by eating prey individuals, and by indirect, sub-lethal effects which alter the behaviour of prey in such a way as can influence survival rates (Bonnington, Gaston, & Evans 2013). Beckerman (2007)determined that even a small reduction in fecundity due to the sub-lethal effects of predation fear could lead to significant reductions in bird abundance (up to 95%).

4.2 Speculation remains however, over whether cats simply take the 'doomed surplus' rather than taking sufficient numbers of prey items to play a significant part in the decline of a species (Beckerman, Boots, & Gaston 2007). Whether or not cat predation can negatively impact on a population depends to some extent on whether mortality is compensatory, in which case the animal would have died anyway from another cause, or additive, potentially having an adverse effect on the population. Baker (2008) suggested that cat-induced mortality was primarily compensatory, with cats mostly taking birds of poorer quality in this study; those with lower fat and pectoral muscle scores.

4.3 Many studies that have examined predation by cats to date have relied on estimates of predation rates and these have primarily been based on the number of prey items returned to an owners' residence. In the US a recent review has suggested that the domestic cats cause far greater wildlife mortality than had previously been estimated; estimating predation levels of between 1.4-3.7 billion birds and 6.9-20.7 billion mammals per year in the US (Loss, Will, & Marra 2013).This work provides a more quantitative approach to the estimation of mortality levels caused by cats in the US and determined, from the results of ten other studies that native species make up the majority (33%) of bird prey items.

4.4 At least 14% of the 238 modern bird, mammal or reptile extinctions recorded by the International Union for Conservation of Nature (IUCN) Red List have been attributed in some way to free-ranging cats on islands (Medina 2011). The situation in the UK has been compared to the hyper-predation observed on oceanic islands (Woods, McDonald, & Harris 2003) the provisioning of food by humans (analogous to a primary prey species) serving to exert an indirect effect on a secondary prey, resulting in the increased number of a predator, in this case the domestic cat. As a result of this reliance on the provision of food by humans, the abundance of cats could exceed the carrying capacity of the environment (Baker *et al.* 2005).

Effects on avian populations

4.5 A great deal of contention exists over whether declines in avian populations over recent decades can, at least in part, be attributed to high cat densities in the UK. Relatively little empirical evidence is available to confirm whether cats have an adverse effect on bird populations, except on oceanic islands, where wildlife is particularly vulnerable to the introduction of a species, due to the lack of evolved defences to novel mammalian predators. The Stephens Island Wren *Traversia lyalli*, for example, is alleged to be the only species to have been brought to extinction, shortly after its' discovery in 1894, by a single animal; a domestic cat introduced onto the island by the lighthouse keeper (Galbreath & Brown 2004). While the account of the birds' extinction has been somewhat over-simplified, predation by one or more cats was likely a contributory factor in its demise and the decline of many other avian species on the island, along with the activities of collectors and habitat loss.

4.6 Few studies have been carried out that specifically consider the effects of cat predation on avian populations in the UK; those that do appear to suggest that predation by cats is not of concern on a national scale but may be influential in the decline of local populations. Other studies in the USA and Australia have mostly drawn similar conclusions.

4.7 Mead (1982) carried out an assessment of the cause of death of recovered ringed birds. Where the cause of death could be identified, over a quarter of the six most frequently recovered species were determined to have been killed by cats. These species, such as the blackbird *Turdus merula*, are ground or low vegetation feeders, making them more vulnerable to predation by mammals. It was recognised that cat predation was a significant cause of death to many avian species examined; however no clear evidence suggested that overall harm to a species population resulted. In a later study by Churcher & Lawton (1987), the prey items taken home by domestic cats in a Bedfordshire village were recorded by their owners over one year. In total, 1090 prey items were recorded, with an average of 14 items per cat per year. It was determined that cats were responsible for approximately 30% of recorded house sparrow deaths within the village that year. The paper concluded that although cats could likely effect local bird populations it was unlikely that this would be the case on a national scale.

4.8 Barratt (1998) studied the prey items brought home by cats over a year in a region of Australia, finding that birds comprised 27% of the prey. Barratt concluded that there was no clear relationship between cat predation and bird population size and that cats were primarily predators of small mammals, with house mice making up the majority of prey items (56%). Without a greater understanding of prey population dynamics the true impacts of cat predation remain uncertain; estimates of predation rates do not alone prove that a population is negatively affected.

4.9 It is important to consider the potential for indirect impacts upon avian populations resulting from cat predation, for example, predation has the potential to negatively impact upon native predators, such as rodent-dependent birds of prey (George 1974). George found that cats were taking large numbers of mammals, depleting the prey available to wintering raptors. Beckerman (2007) examined sub-lethal effects of cat presence; that is, the fear of predation and the potential effects of this upon the life history traits of birds and survival rates. It was concluded through the use of models that sub-lethal effects may suppress bird numbers sufficiently to affect population numbers.

Effects on mammal populations

4.10 It would appear from various studies that birds may not be the principal prey for domestic cats and instead, cats are primarily predators of small mammals, such as rodents and rabbits (Hansen 2010). Churcher (1987) recorded that 35% of the total recorded number of prey items were birds and Woods (2003) later reported that almost 70% of all prey returned by domestic cats in the study were mammalian. It remains unclear, however, whether cats have a significant impact on vulnerable mammal populations. Baker (2003) studied the distribution of small mammals in urban areas of Bristol and found a negative relationship between the number of wood mice *Apodemus sylvaticus* and the number of cats in suburban gardens.

4.11 Liberg (1984) investigated the impacts of cat predation on natural populations in Sweden by analysis of scats. Rabbits were the most important prey item, with cats moving to other prey items, such as rodents when the population of rabbits fell. It was determined that rabbit density was ultimately the key factor in choice of prey. It was also observed that cats would tend to catch weaker or more vulnerable rabbits, suggesting that mortality resulting from cats was compensatory rather than additive in that study. Moller (1999)looked at the health of birds caught by cats compared to the health of those that died from other causes by examining the size of their spleens; finding that those caught by cats were in poorer health.

4.12 More recently, a study was carried out to identify the level of bat mortality caused by cats in a region of Italy based on records from four wildlife rescue centres between 2009 and 2011(Ancillotto, Serangeli, & Russo 2013). Predation by cats was the primary cause of admittance to the rehabilitation centres and accounted for 28.7% of adult bats admitted. Adult female bats in the summer were most often affected, with cat predation having the potential to therefore affect breeding colonies. In the UK, following inferences from the data by Woods (2003), it was suggested that 250,000 bats are killed every year by cats (Altringham 2011).

Reptiles and invertebrates

4.13 Reptiles and amphibians are not considered to be the primary prey of cats; however, various studies show that cats are effective predators of herpetofauna. Woods (2003) found that reptiles and amphibians comprised 1% and 4% of all prey items respectively of a total of 14,370 prey items returned throughout the duration of the study. Species killed included slowworms, grass snakes and sand lizards and it was found that where the cat was located within the UK significantly affected the number of herpetofauna brought home; the number decreased with increasing latitude. This general trend reflects the overall differences in species distribution, with the highest numbers brought home in the south east. It was observed in this study that the number of reptiles brought home was reduced in households that provided food for birds and that cats kept indoors overnight would bring home more herpetofauna.

4.14 A study looking at the decline of the sand lizard *Lacerta agilis* along the Sefton Coast was carried out to determine whether cats could be considered as a significant predator of this species (Henshaw 1998). Anecdotal evidence and the GPS tracking of cats confirmed that cats did hunt in areas where sand lizard colonies are present and that cats could be considered to be a dominant factor in the species' decline. It has also been observed that cats in the UK have been capable of killing adders *Vipera berus* (Langton *et al.* 2005).

4.15 Some records exist relating to the predation of invertebrates, such as dragonflies, by domestic cats. Anecdotal reports of cats killing dragonflies have been recorded by the Dragonfly Society including a Migrant Hawker *Aeshna mixta* and a Southern Hawker *Aeshna cyanea* (Goddard 2003; Emary & Emary 2004)

Potential benefits

4.16 Conversely, some have suggested that domestic cats could provide a net benefit to wild populations, by the removal or suppression of other pests and predators, such as rats (Hansen 2010). In Hansen's study in New Zealand, 48% of the total prey taken by cats were rodents; with little observed impact on native populations of birds, lizards or invertebrates. Cats can also still play an important role in pest control, for example in controlling the common rat *Rattus norvegicus* or the house mouse *Mus domesticus* in the UK.

Overall animal welfare implications

4.17 While cats are efficient predators which are capable of swiftly dispatching prey, there are nonetheless significant animal welfare issues that arise from high levels of cat predation. Cats are opportunistic hunters and will often play with their prey before killing it, for example when a mother is teaching her kittens to hunt. Prey species may suffer greatly for hours or days as a result of this and if not killed directly may succumb to various injuries or infection.

5. Cat home ranges and distance travelled to hunt

5.1 The home ranges and the distance travelled to hunt by domestic house cats and feral cats have been considered in a number of studies, traditionally through the use of radio-tracking and, more recently using GPS. The movement of animals through specific sites and habitats, the size and shape of a home range and the overlap between different ranges are important factors in understanding cat behaviour and subsequently the protection of vulnerable species from the threat of cat predation. With the increasing levels of development in the UK, and duties now in place in legislation and planning policy to protect biodiversity, it is necessary to understand the potential level of disturbance that could result from increased numbers of pet cats over a particular area, particularly areas close to sensitive wildlife reserves.

Home range

5.2 The home range of an animal may be considered as the area in which the animal spends its' time carrying out its' routine activities and may vary, for example, with habitat type and prey availability. The spatial distribution of a species is determined primarily by food availability, the habitat type and by social organisation. A summary of various studies that have investigated the home ranges of domestic cats, both owned and feral, is given in Table 2.

Table 2: Summary table of mean hunting ranges (±sd) of cats (hectares) from Minimum Convex Polygons with sample sizes in parentheses

Source	Hunting Range	Location
Warner (1985)	Mean male hunting range of 228.4 ± 100.3 (4). Female mean hunting range of 112.4 ± 21.1 (7)	Illinois, USA
Langham & Porter (1991)	Nocturnal and diurnal home ranges of feral cats Nocturnal: Male mean range of 239 ± 97 (4) and female 154 ± 21 (9) Diurnal: Male mean range of 134 ± 85 (7) and female 91 ± 67 (12)	New Zealand
Barratt (1997)	Diurnal and Nocturnal ranges of farm and suburban areas Diurnal: Farm 5.65 ± 7.35 (7) and Suburban 5.57 ± 11.67 (10) Nocturnal: Farm 6.01 ± 2.27 and Suburban 11.59 ± 15.83	Canberra, Australia
Meek (2003)	2.29 ± 1.13 (15) Mean male home range of 4.2 ± 2.6 and female home range of 2.4 ± 1.3	Jervis Bay, Australia
Biró (2004)	Yearly mean of 41-328 (3)	Hungary
Lilith (2008)	In rural areas a hunting range of 0.07-2.86 was calculated and in urban areas a range of 0.01-0.64 (16)	Western Australia
Hansen (2010)	4.78 ± 1.62 (8) Nocturnal home ranges of 0.46 - 14.0 and diurnal home ranges of 0.22-10.65	New Zealand
Metsers (2010)	26 ± 7 (38)	New Zealand

5.3 The movements of domestic cats are not influenced by food distribution, allowing them to reach artificially high densities (Turner & Bateson 2000). Male home ranges can be up to three times that of a females', with male ranging behaviour being potentially limited by access to females. The home ranges of male and female domestic cats may possibly overlap, but until recently overlaps were not generally expected except for animals with shared owners (Barratt 1995). Emerging studies are now suggesting that sharing home ranges in 'shifts' may be increasing domestic cat density even further. Barratt (1997) studied the home ranges of two cat colonies in New Zealand, one on the edge of a suburb with adjoining woodland habitat and another colony of farm cats. He concluded that the home range sizes of cats were determined by the density, spatial distribution and the social dominance of cats. Both suburban and farm cats spent the majority of their times within close proximity to their homes or the farm.

5.4 A study by Metsers (2010) monitored 38 domestic cats using GPS tracking devices at three sites (one rural and two on urban fringes), with a view to understand the potential benefits of exclusion zones on a threatened lizard species in New Zealand. Home range sizes varied at the rural and urban edge sites, with larger home ranges observed at the rural site (0.3-69ha) compared to the urban areas (0.35-19ha and 0.2-9ha). Home range size was not related to hunting success.

5.5 Hansen (2010) studied the home ranges of cats within an area of New Zealand using GPS collars and found that the home range sizes for the 100% minimum convex polygon varied between 0.7 and 13.4ha for domestic cats. Confirming earlier studies of this sort, nocturnal home range sizes were significantly larger than diurnal ranges (Hansen 2010; Metsers, Seddon, & van Heezik 2010). That said, domestic cats have become somewhat diurnal in nature, perhaps reflecting their adaptation to life with humans (Fitzgerald & Turner 2000). A four year study of wildcats and domestic cats in Hungary using radio-telemetry confirmed that male ranges are larger than those of females and overlap between male home ranges is also greater than that of females (Biró, Szemethy, & Heltai 2004).

5.6 Feral cats have been observed to have larger home ranges than their domestic counterparts due to their need for self-sufficiency in the absence of subsidisation from humans (Liberg 1984); this was later also confirmed in a study by Horn (2011). The home ranges of feral cats were considered in New Zealand by Langham and others (1991) along with any potential seasonal changes in home range size. Male home ranges were larger than those of females and nocturnal home ranges were larger than diurnal ones (Table 2). No consistent trend in home range size was observed in females with changing season. The larger home ranges observed for males may be due to behavioural and physiological reasons, with males occupying larger, exclusive territories which will incorporate the home ranges of several females (Langham 1991).

Distance travelled to hunt

5.7 In addition to the home range size of cats, the maximum linear distance travelled has also been examined in several studies which are summarised in Table 3. The straight-line measurements do not tell us how far a cat has travelled in total, rather the maximum distance travelled from home from one point to another, therefore, cats may travel considerably greater distances than some studies suggest.

Table 3: Summary of distances (metres) travelled by cats in a straight line

Source	Distance	Location
Warner 1985	956-3013	Illinois, farm cats
Page & Others, 1991	Mean max distance travelled between 2 points 1107 ± 589 for 2 males	Avonmouth, UK
Barratt, 1997	Mean distance travelled from home 311. (20-940).	Canberra, Australia
Meek 2003	Max 1170	Jervis Bay, Australia
Lilith 2008	300	Western Australia
Hansen 2010	80-301 (mean of 199 ± 32).	Banks Peninsula, New Zealand
Metsers 2010	180 – 229	Dunedin, New Zealand

5.8 There are also a number of anecdotal distances for cats travelling from home. Green (pers. comm.) recorded a domestic (tame) cat hunting rabbits 3km from the nearest house and a cat known to the observer to have come from a particular house was recorded hunting on heathland 1100m from its home base (Underhill-Day pers. comm.). Cruikshank (pers. comm.) attached a GPS collar to a young female cat and over a twelve hour period the cat made a number of excursions including crossing a main road and a railway with one excursion taking it 3.4 km in a straight line from its home base.

5.9 Morgan *et al.* (2009) considered the impacts of domestic cats living close to a wetland reserve in New Zealand and concluded that predation by cats poses a significant threat to wetland species. Cats living close to the reserve brought a wider range and number of prey species home than those living further away and younger cats would venture further into the wetland than older animals.

Cat density

5.10 An analysis of twenty years of records in Auckland, New Zealand, was recently carried out to identify the spatial characteristics of 'unmanaged' cat colonies (Aguilar & Farnworth 2013). The results of this study showed a direct relationship between the spatial distribution of cats and human population distribution, with distinct clustering observed in areas of high human density. Concerns are raised over the welfare implications of such high cat densities, with observations that those cats from colonies exhibiting greater incidences of cat flu, greater flea burdens and also the potential for the spread of zoonotic disease, such as *Toxoplasmosis* (Dabritz & Conrad 2010). Cats shed oocysts of *Toxoplasma gondii* in their faeces, posing a threat to the health of wildlife.

6. Mitigation of the effects of cat predation

6.1 Various studies have been carried out to assess the effectiveness of a range of methods to deter cats from hunting, with mixed results. Many devices or methods to alter the behaviour of cats have been tested, such as the use of bells and other physical devices or attempts to modify behaviour by, for example, altering diet or restricting the amount of time, or time of day, that a cat is able to spend outside. To date, no methods to alter the behaviour of cats have completely prevented predatory activity.

Bells and collar mounted devices

6.2 An eight week study looking at the effectiveness of bells at reducing the number of prey returned home to owners found that on average, 2.9 prey items were brought home per cat while wearing a bell, while 5.5 items were returned when not wearing a bell. Overall, there was no difference in the relative numbers of each prey type delivered (Ruxton, Thomas, & Wright 2002). Woods (2003) found that cats with bells brought home fewer mammals than those without; with bells possibly acting as a warning to mammals of the presence of a predator. Bells did not, however, alter the numbers of birds or herpetofauna returned in this study.

6.3 A later study by Nelson and others (2005)showed that cats wearing a bell returned 34% fewer mammals and 41% fewer birds than those with a plain collar. The use of ultra-sonic devices on the collars of cats led to the return of 38% fewer mammals than those wearing a plain collar. Bells have been shown to reduce total predation in other studies, with experimental studies in New Zealand showing a reduction in predation by more than half (Gordon, Matthaei & Van Heezik 2010).

6.4 Calver and others (2007) studied the effectiveness of a novel collar-fitted pounce protector, called the CatBib™; a lightweight and flexible neoprene device fitted by Velcro to a cats' collar, hanging in front of the chest. The prey items returned by 56 cats in Perth, Australia that were 'known hunters' were recorded over a period of six weeks; cats were studied without the device for three weeks and for three weeks with the device, with or without a bell. A reduction in hunting activity was observed while cats were wearing the CatBib™, with or without a bell; 81% of cats were stopped from catching birds, 33% from catching herpetofauna and 45% from mammals. It was also observed that different colour CatBibs had no significantly different effects and that over time the effect of the treatment did not decline. Interviews with owners also suggested that some cats stopped hunting activities after a period of using the CatBib™.

Modification of cat behaviour by owners

6.5 Studies have questioned whether the type of food fed to domestic cats can influence hunting frequency and therefore the number of prey items returned, with evidence suggesting that the feeding of high quality food or alteration of feeding patterns have no impact in the reduction of hunting behaviours. In Hansens' study (2010) it was observed that those cats fed on a regular diet high in fresh meat had significantly higher rates of hunting activity. This observation was consistent with an earlier study; finding that those cats only fed meat caught more birds than those with a dry-food diet

(Morgan 2002). It is thought that the high protein content of fresh meat stimulates the production of serotonin, a hormone associated with mood and body rhythms.

6.6 Altering the amount of time spent outside by cats can alter their hunting behaviours. Woods (2003) found that those cats kept indoors overnight brought home fewer mammals and more herpetofauna than those allowed out during the night. There was no difference observed in the number of birds returned. With the nocturnal behaviour of wild mammals, it would follow that keeping a cat indoors overnight will reduce its' ability to hunt nocturnal prey. Restricting the amount of time a cat is able to spend outside has potential benefits to wildlife, as well as possibly providing better welfare for the cat itself by reducing potentially aggressive interactions with other cats and reducing the risk of injury through accidents.

6.7 Cat curfews have been introduced in some parts of the USA and Australia, however their effectiveness is still uncertain. In Australia, cat curfews along with educational campaigns to help change attitudes to cat predation, with some positive results, such as the increased survival of a threatened species of lyrebird *Menura novaehollandiae* (Pergl 1994).

Cat exclusion zones and fencing, and preventing the keeping of pets in new development

6.8 The implementation of exclusion fencing has been tested as a possible means of predator exclusion. Day & MacGibbon (2002) found that a mesh of 50mm would exclude both adult and juvenile cats, that cats could jump to at least a height of 1.8m and that at fence corners, cats could make use of opposing fence lines to clear the fence where the fences joined at less than 120°. They also found that some cats, in contact with an electric wire became more frenzied and vigorous in their attempts to climb the fence and could be more successful as a result.

6.9 A later study by Moseby &Read (2006) examined the effectiveness of 1.8m fences with a foot apron and floppy overhang top as a means of excluding feral cats and foxes in Australia. The trials were conducted as 'pen' trials followed by field trials with paddock scale exclosures. Both proved effective with "most cats". They found that reducing the height of the fence in pen trials to 1.15m was still effective but this was not tested in field trials. A 60cm overhang precluded more cats than a 30cms overhang, steel posts were more effective in precluding climbing cats than wooden posts and the efficacy of the fences was further improved by offset electric wires at heights of 120cms and 150cms. Foxes could chew through 0.9mm gauge netting and cats could follow them through the holes thus made. Foxes did not successfully chew through 1.2mm gauge netting. Size or sex of cat didn't influence its' ability to escape. One proposed disadvantage to this type of exclusion was the potential restrictions to movement of non-target large species, in this study, kangaroos and emus. Visual repellents, such as those used to reduce bird collisions with deer fences in the UK were proposed as a potential solution. The authors were careful to confine their conclusions to arid desert habitat in Australia and had no knowledge of foxes and cat's prior experience of negotiating fences.

6.10 A contemporary study by Robley et al (2006) used six fence designs with and without electric wires at various heights. Fences were 1.8m high and cats were unable to breach these with or without electric wires. No assessment was made of corners. The authors recommended a 1.8 m fence with 60cms overhang to exclude cats.

6.11 A further study by Day & MacGibbon (2007) was carried out in a number of locations and using fine mesh to exclude even small animals, such as mice, using three fence designs. Once again they found that electric wires would not prevent climbing by determined cats even after experiencing a number of shocks. However a 1.2m fence with a 1.5-2m angled top using fibreglass rods and plastic netting was not crossed by cats, and nor was a 2m fence with a rolled sheet steel top attached horizontally and extending out from the top of the fence by 33cm. This study continued to record the success of fences for a period of years and found that re-invasions occurred in 50% of cases due to gates being left open, constructions or vehicles left near the fence allowing animals to cross or tree falls crushing fences. Re-invasions occurred in some cases within six hours of fence failure at which time repairs were carried out but not when repairs were carried out within three hours. Most of the tested sites were in rural location with some on islands.

Day & MacGibbon concluded that re-invasion should be treated as a ‘when’ not ‘if’ probability and that re-invasion of areas protected by fences is a significant risk. They recommended that the risk could be reduced by meticulous construction and maintenance, by double gates at both pedestrian and vehicle access point, gate alarms and surveillance systems to provide live monitoring at all times. They did not test the probabilities of re-invasion in urban situations where there is a risk of fence cutting or vandalism, or the placing of material against fences increasing the risk. It is not known whether any of the tested fences were in areas where they might be dug under by larger burrowers such as badgers.

6.12 More extreme measures to potentially limit the predation of vulnerable wildlife by cats have recently been considered, such as the introduction of cat exclusion zones around sensitive wildlife areas (Metsers, Seddon & van Heezik 2010). It was determined that in order to provide a suitable buffer, an exclusion zone of at least 2.4km would be required in rural areas and 1.2km in urban fringe areas and would need to take into account factors such as variation between individual cats, habitat type and the degree of development found nearby. An earlier study by Barratt (1995) recommended a buffer zone for species threatened by night time cat hunting of 1000m following the finding that one of the studied cats moved 900m at night (two others moved 810m and 760m respectively). Lilith and others (2008) determined that a buffer zone of 360m would be required to reduce intrusions by cats into nearby native bushland after it was observed that the maximum distance travelled by one of the studied cats was 300m. The monitoring of such schemes and long term impracticalities may pose significant problems however.

6.13 A number of Inspectors at planning inquiries have accepted the risk that is posed to wildlife on nearby sites from predation by pets (e,g, Planning appeals at 2, Petwyn

Close, Tricketts Cross, Ferndown, Dorset, APP/U1240/A/04/11166659, at 6, Dudmoor Farm Road, Christchurch, Dorset, APP/E1210/A/10/2125281, at 163a Phelipps Road, Corfe Mullein, Wimborne, Dorset APP/U1240/A/09/2119151/WF). In his decision, the Inspector in the inquiry into the construction of 4 maisonettes and six houses at Vicarage Road Camberley, Surrey (APP/N1730/A/05/1175412) accepted that cats could be a potential menace to nesting birds and chicks up to one km from their base and in considering the Surrey Heath local Plan, the Inspector noted that some cats would almost certainly enter the SPA, and that birds nesting on the ground or in low scrub would be especially vulnerable including woodlarks, nightjars and Dartford warblers.

6.14 There has been significant debate in recent years relating to the effectiveness of 'cat proof fencing' to prevent domestic cats entering into Special Protection Areas (SPAs), which are wildlife sites classified in accordance with the European Birds Directive, and aim to protect species of bird of European conservation importance due to their rarity and vulnerability. A number of heathland SPAs in England are classified for their ground nesting or low nesting bird species, whose nests are vulnerable to predation by domestic cats. Natural England and the RSPB have objected to new development in very close proximity to heathland SPAs for a number of years, with objections to development around the Thames Basin Heaths being widely publicised. Natural England has continued to maintain that the effectiveness of cat proof fencing is unproven, and do not support the inclusion of cat proof fencing as a mechanism to prevent nest predation by domestic cats in new development. Alternatively, Natural England has recommended a 400m development exclusion zone around a number of heathland SPAs. A key planning decision in 2012, within 400m of at Talbot Heath, a site which forms part of the Dorset Heaths SPA, confirmed the view long held by Natural England and the RSPB that cat proof fencing is not a fail-safe means of preventing access by domestic cats, and certainly should not be relied upon to prevent harm to SPA interest. The Secretary of State (SoS) overturned the decision by the Borough of Poole Council to grant permission for housing and student accommodation (– APP/Q1255/V/10/2138124), having regard for the long term ineffectiveness of both cat proof fencing and covenants to be placed on the new property to prevent the keeping of pets.

6.15 In confirming the Inspector's recommendations, the SoS agreed with the Inspector that little weight could be placed on the long term effectiveness of the no-cat or dog covenant in preventing the keeping of these pets within the new development. He therefore considered that any mitigation scheme would need to be heavily reliant on the efficacy of the cat/people proof fence. The SoS shared the concerns of NE and the RSPB regarding the more general efficacy of a linear fence. In particular, he agreed that cats would still be able to enter Talbot Heath round the end , and that there would be potential for deliberate breaching of the fence by people in view of the direct route to key destinations. Overall therefore, having regard to the requirements of the Habitats Regulations, the SoS gave significant weight to the advice from NE with regard to the proposed mitigation measures and agreed with their overall conclusion that the proposed development on its own was likely to have a significant adverse effect on the integrity of the international sites.

6.16 Similar decisions have previously been made by local planning authorities, and where necessary the Planning Inspectorate, which refute the effectiveness of cat proof fencing and no cat covenants, on the basis of advice given by Natural England, often accompanied by evidence presented by the RSPB. Numerous test cases, including the appeals dismissed for 5 bungalows with a cat proof fence at 55/57 Oaks Drive Ringwood (APP/U1240/A/06/2015733) and 9 houses at Ringwood Road, Ferndown, Dorset (APP/U1240/A/06/2014196) which included a no-cat covenant, appeared during the formulation of planning policy to exclude residential development within 400m of heathland SPAs in the south east and south west. In a number of cases Planning Inspectors have accepted that cat proof covenants could be effective in relation to managed accommodation such as flats (e.g. 50 Dewlands Way, Verwood, Dorset APPU1240/A/03/1108797, Greenmantle, Knightsbridge Road, Camberley, Surrey APP/D3640/A05/1196831). More recently, with the exception of a few large scale proposals such as the one at Talbot Heath in 2012, the planning policy now embedded in local plans effectively guides applicants and prevents such applications being made.

Other possible methods

6.17 Other devices, such as ultra-sonic deterrents are available to reduce the intrusion of domestic cats into gardens and may prove useful for those who wish to prevent cats accessing their gardens for example. Nelson and others (2006) tested the efficacy of an ultrasound deterrent called CATwatch and determined that it provided a moderate deterrent effect. In the first of two experiments it reduced the probability of a cat entering a garden by approximately 32%; but did not reduce the probability in the second experiment. However the average duration of an intrusion by a cat was reduced by between 38% and 22% in the two experiments. CATwatch works by detecting movements and body heat and then triggering an ultrasonic alarm. While such deterrents may prove useful in reducing intrusions by cats, it was important to take into careful consideration the positioning of the device. The tests were carried out in dwelling house gardens and no tests of such devices could be found which attempted to exclude cats from larger areas.

6.18 While neutering would not serve as to bring about a reduction in hunting behaviour, it could act as a means of reducing the population of feral cats. ‘Trap-Neuter-Return’ programmes have been carried out in the USA and have had limited success in reducing the number of feral animals. Other physical methods to reduce predation, such as declawing of cats, should not be encouraged as it is unlikely to prove effective and is considered unacceptable on ethical and welfare grounds (Fiore & Sullivan 2005).

7. Discussion

7.1 As the requirement for development in the UK continues to rise, it is important to gain an understanding of how the increased human population and thereby the population of domestic pets could impact upon the environment. In particular, where developments are placed within the locality of protected wildlife sites, such as lowland heathland, it is prudent to consider the wider impacts of this urbanisation.

7.2 The potential impact of the domestic cat on the environment is an issue which remains a contentious and somewhat emotive. While public concern exists over the significant threat that pet cats may pose to wildlife, such as garden birds, whether or not this predation has a wider detrimental effect on wildlife populations and communities still remains unclear. Many reports of prey population declines are anecdotal, with few studies confirming that domestic cats do or could have the potential to take an unsustainable harvest of a species.

7.3 The results of many studies carried out to date should be considered in light of several limitations. The majority of investigations into the predation rates of cats have relied on the habit of cats to return some of their prey to their owners' residence and for owners to actively participate in recording; since cats do not bring all prey home, the level of mortality is invariably underestimated overall. A bias is perhaps to be expected towards owners with an interest in wildlife and conservation issues; on the other hand, some cat owners may be keen to demonstrate the hunting ability of their animals, while others may feel it unimportant to record that their cat does not hunt.

7.4 Research studies carried out into the effects of predation by cats are often localised, which do not offer a clear representation in the wider population. Various factors need to be taken into consideration when examining the wider effects of cat predation, such as habitat features, prey type and availability and factors which may affect cat behaviour. Owner profiles need to also be considered to gauge the level of understanding that pet owners have about the activities of their animals, or indeed, whether they are concerned about hunting by cats. Without a firm understanding of the population dynamics of prey species, determining whether or not a population is affected by cats will remain difficult.

7.5 The impacts of cat predation may be most greatly felt when housing is placed close to important sites for nature conservation wildlife sites. Cats have been recorded taking Dartford Warblers *Sylvia undata* and other heathland species, such as linnet *Carduelis cannabina* (Bibby 1979). During a PhD study of Dartford Warblers, Murison (2007) recorded that of 31 young Dartford warblers ringed at the nest on two urban heaths, five were known to have been predated by cats within 2-4 weeks of leaving the nest. This represented a minimum predation rate by cats of 12.5% of the known production of fledged young from these sites in that year.

7.6 Cat predation is only one of a large suite of factors to consider which may limit prey populations, including habitat loss and disturbance, agricultural land change, climate change and competition, all of which are also relevant to planning decisions. However, it is apparent that there is an increasing need for planning bodies to take account of the potential impact of the domestic cat on biodiversity, and the limited means available to deter hunting behaviour, or exclude domestic cats from sensitive locations within their home ranges. Essentially, sensitive wildlife areas are most effectively protected by informed spatial planning that prevents large scale residential development in locations where biodiversity interest could be significantly affected by cat predation.

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