# REGULATION OF FREE-ROAMING CAT (*FELIS SILVESTRIS CATUS*) POPULATIONS: A SURVEY OF THE LITERATURE AND ITS APPLICATION TO ISRAEL

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**Abstract** *Animal Welfare 2002, 11*: 171-188

*Following domestication of the cat about 5000 years ago, it followed man into many areas of the world. The vast resources available in urban environments have led to increasing numbers of free-roaming cats on the streets. The high population density of these cats and, in many cases, the lack of suitable nourishment and veterinary care, is conducive to their poor condition of health. They are frequently perceived as a nuisance to human society. This article surveys the different methods of management of free-roaming cat populations, focusing on the urban environment, and discusses the animal welfare implications and the advantages and disadvantages of each method.*

**Keywords**: *animal welfare, domestic cat, eradication, population control, sterilisation*

## Introduction

The domestic cat (*Felis silvestris catus*) was domesticated about 5000 years ago by the ancient Egyptians. It is generally accepted that domestication was of the African subspecies (*Felis silvestris libyca*), derived from the wild cat *Felis silvestris* (Bradshaw 1992). Very little selective pressure was exerted during the process of domestication, as expressed in the relatively few morphological and behavioural changes (Serpell 1988; Bradshaw 1992). Following its domestication, the cat became widely distributed by man in many areas of the world. Unlike other mainly nocturnal predators, the domestic cat is also active by day (the extent of activity depends on the season and food availability), mainly during the early morning and at dusk (Izawa 1983; Miramovich 1991). It is an obligate carnivore both in its nutritional requirements and in its methods of ingestion, digestion and metabolism (Bradshaw *et al* 1996). Natoli (1994) categorised the domestic cat according to environment, as follows:

*1. Urban cats*: cats living among human society. This category comprises: a) Cats living exclusively indoors. These cats do not hunt and are completely dependent on food supplied by their owners. b) Cats inhabiting urban streets. These cats feed on resources supplied by man either directly (feeding) or indirectly (eg garbage). They do not rely on hunting to supply their nutritional needs. c) Intermediate between categories a and b. These cats belong to a household, but also roam outside. They come into contact with cats belonging to category b. Although mostly dependent on food supplied by their owners, they also have access to the resources of cats in category b.

*2. Rural cats*: Free-roaming cats in a rural environment. These cats are partially dependent on food supplied by their owners, but also hunt prey.
*3. Feral cats*: These cats live without human contact in a natural environment, having lost all dependence on man, and sustain themselves mainly by hunting (Natoli 1994). They are also able to scavenge on human garbage if they live in the vicinity of such resources (Liberg & Sandell 1988).

For the sake of convenience, in this survey we shall term all cats (urban and rural) that do not belong to a specific household (categories 1b and 2) 'street cats', whereas cats that belong to a particular home (categories 1a and 1c) will be termed 'pet cats'. Street cats and pet cats that also go outdoors (categories 1b and 1c) will both be termed 'free-roaming cats'. Cats of category 3 will be termed 'feral cats'.

**Spatial organisation**

The variety of social behaviours and the social structure of domestic cats stem from the wide variety of habitats in which the cats live (Leyhausen 1988). The differences in urban habitats are directly influenced by man, who controls both the distribution and availability of resources (Miramovich 1991). The spatial organisation of free-roaming cats can be roughly divided into three density levels:
1. Low density populations numbering 1–5 individuals per $km^2$: found in rural or outlying areas, where almost all of the cats' food is caught by hunting (Liberg & Sandell 1988). These cats share a similar social structure to small wild cats — solitary organisation. Because most of their food is prey, and their typical hunting method is to pounce from ambush, sociality is limited (Izawa & Doi 1993).
2. Medium densities of 5–50 cats per $km^2$: found in rural areas, where the cats are supplied with only part of their nutritional needs by humans. Female kin live in social groups in the same territory, but separated from other neighbouring female dynasties (Liberg & Sandell 1988).
3. High densities of over 50 cats per $km^2$: found only in cities, where available resources are plentiful (Liberg & Sandell 1988). A survey carried out in Jerusalem found a density of 2300–2800 cats per $km^2$ (Miramovich 1991). In urban areas, facilitated by the high quantity and availability of resources, two main social patterns have been observed:

*Defined social pattern*: Groups of females, with overlapping of territory between groups of kin and complete separation between neighbouring but non-related groups. The adult males dwell individually in larger territories. Male territories overlap but do not display a group pattern (Liberg & Sandell 1988; Izawa & Doi 1993).

*Flexible social pattern*: Males and females with overlapping territories, habituated to each other's presence and sometimes sharing a 'neutral' area where neighbouring cats may experience social contact. Great flexibility is displayed in the social behaviour and social structure of these cats. For example, individual cats may occupy extremely large territories in one case and very restricted ones in another; several males may share territories with several females, or one male may share a territory with several females (Leyhausen 1988).

These differences in spatial organisation can be explained by the 'resource distribution theory': the spatial distribution pattern of individuals within a population is influenced by the distribution of important resources in the habitat (Miramovich 1995). Access to vital resources is also an important factor. When the amount of resources (particularly food, water and refuge) is predictably high and freely available in a particular area, cat density will

increase in that area (Izawa & Doi 1993). Clumped food resources (patches) favour cat aggregation, whereas evenly distributed (small) food resources favour cat segregation.

Street cat populations comprise two sub-categories (Mahlow & Slater 1996): first, pet cats neglected or abandoned by their owners; and second, successive generations of free-roaming cats. Reproduction in street cats is intensive because of the seasonal oestrous cycle of the females, during which each female comes into heat several times until pregnancy or end of the cycle. Successful copulation ends in a 64-day pregnancy (Mahlow & Slater 1996) and delivery of a litter with a measured median size of four kittens (Bradshaw *et al* 1999). The females return to their normal cycle during suckling or immediately after the young are weaned (Mahlow & Slater 1996).

The number of street cats in the USA is estimated to be 10–50 million (Mahlow & Slater 1996), while the number of pet cats is estimated at 60 million. The latter number is based on telephone market surveys carried out by cat-food manufacturers (Patronek & Rowan 1995). Because the spatial distribution of free-roaming cats varies according to the food patches in the area (Miramovich 1995; Natoli 1994), it is difficult to estimate the number of free-roaming cats in a large area such as a city.

**Survival**

Only 10 per cent of young cats in an urban environment (Rome) were shown to survive their first years of life (Natoli 1994). A similar survival rate was found for a cat population in a Japanese fishing village (Izawa & Ono 1986). It would appear that a high population density of street cats increases the risk of disease (Kerby & Macdonald 1988). Because cats belonging to the same social group may cooperate in caring for the young, a large number of kittens may play, sleep and eat together and thus inter-transmit disease (Natoli 1994). On the other hand, it is also possible that in groups in which several mothers suckle each other's young, the kittens may acquire a wider range of antibodies from the milk, and thus acquire a greater level of immunity (Kerby & Macdonald 1988). In addition to diseases, mortality factors in young cats include infanticide — the killing of young by strange males (Kerby & Macdonald 1988) — and death resulting from abandonment by the mother or her disappearance.

The survival rate of adult cats over the age of one year, as quantified in the Japanese fishing village, was 90 per cent (Izawa 1984). Mortality factors in adult cats include:

*Disease*: Feline immunodeficiency virus (FIV) and feline leukaemia virus (FeLV), amongst others, are diseases for which the risk of infection rises with increased population density. Infection is transmitted via biting, allogrooming and communal feeding and is also transmitted from mother to offspring (Fromont *et al* 1997). A study carried out in England revealed that 20 per cent of cats surveyed were in poor physical condition because of injury from fighting, respiratory diseases, exhaustion and roundworm infection (Remfry 1981).

*Road accident*: This mortality factor is significant mainly in cities. A study carried out in Baltimore, USA, showed that most of the cats killed on the road were adult males (Childs & Ross 1986).

*Eradication programs*: The most calculated and significant influence of man is reflected in the planned eradication of street cats, generally involving the trap and euthanasia method (Mahlow & Slater 1996).

**Positive and negative aspects of the presence of free-roaming cats in urban environments**

***Positive aspects***

*Predation of rodents*: The influence of cats on rodent pest populations in an urban environment has not, as yet, been methodically studied. However, even if it would appear that an adult cat cannot prey upon an adult rat (*Rattus rattus* or *Rattus norvegicus*), it is possible that it can predate juvenile rats and may regulate other rodent populations such as mice. A study carried out in Rome revealed that trapping of house mice (*Mus domesticus*) was harder in an environment inhabited by cats, possibly because of a lower population density of mice (Natoli 1994). In a study that examined the nutritional components (from faecal contents) of a rural population of free-roaming cats in New Zealand (n = 361), it was found that mammals constituted the most significant prey, both numerically (76%) and in weight (74%). The house mouse was the most common prey (50%) but comprised only 12 per cent of total prey weight. Rats were less common prey (20%), but comprised a higher percentage (39%) of total prey weight (Langham 1990).

*Anti-depressive effect*: Many cat-lovers are elderly and/or lonely individuals and their care for these cats provides consolation and adds meaning to their lives (Natoli 1994). A telephone survey carried out in Brooklyn, USA, found that a significant (40%) number of those who fed cats on a daily basis were within the 70–79 age range, and that 80 per cent of the cat feeders were women. It is conjectured that those who experience positive interaction with free-roaming cats lower their risk of death by reducing the mental and physical stress of social isolation that can result in a depressed immune system. Such interactions are more frequent in cities than in rural areas. In so far as the survey reflects the situation in New York as a whole, then New York is home to 205,860 humans feeding street cat populations on a daily basis (Haspel & Calhoon 1990).

*Educational influence*: In a world in which increasing numbers of areas are undergoing urbanisation, the presence of cats constitutes a source for animal behaviour and nature studies (Natoli 1994).

***Negative aspects***

*Public health*: Cats can be the source of a wide variety of zoonotic diseases, such as toxoplasmosis, cat scratch disease, rabies, intestinal parasites and plague (Southam 1981; Patroneck 1998). High cat concentrations may also lead to outbreaks of flea and tick infestation in the area (Ablett 1981).

*Animal welfare*: As detailed in the section 'Survival', street cats, and especially kittens, suffer from a variety of diseases in addition to uneven availability of vital resources. Because most of them receive no medical treatment, vaccinations or proper diet, they often suffer from hunger and pain (Bronson 1981; Remfry 1981; Izawa 1984; Kerby & Mcdonald 1988; Natoli 1994) and consequently live a relatively short life (Childs & Ross 1986).

*Hygiene*: In an urban environment with a high concentration of cats, one will frequently encounter cat excreta, scattered garbage and empty food containers (Natoli 1994). Such areas will also usually emanate a strong odour resulting from urine marking by tomcats. In places where cats are fed by humans, the food remains and food containers frequently left in the area constitute a health hazard (Natoli *et al* 1999).

*Noise*: During the reproductive season when the females are on heat, the males howl at each other, often constituting a nuisance (mainly when this takes place at night). Such loud vocal encounters can also occur outside the reproductive season, however, and at all hours of the day (Neville 1983).

*Aesthetics*: Mainly among urban populations, there are complaints regarding the presence of free-roaming cats (usually relating to cats in a poor state of health, or to kittens), cats run over on the road or found dead from other circumstances, and cats that dig defecation holes in private or public gardens (Ablett 1981).
*Endangering wild animals*: A year-long study was carried out in England on hunting activity by pet cats. An isolated village with a large population of pet cats was chosen as the study site. Despite all of the studied cats being given a plentiful supply of food, 1090 prey items caught by the cats were collected, of which 535 were identified as mammals and 297 as fowl. It was found that these cats hunted only in order to satisfy their hunting instinct, and that they had caused a mortality rate of at least 30 per cent of the village sparrow population. Not every prey item caught was brought back by the cat to its home (a further study found that cats brought home about 50% of their prey; George 1974), indicating that the actual number of prey animals caught is higher than that found in the study (Churcher & Lawton 1987). A similar effect but with a more serious outcome — an extreme threat to local wildlife — was observed on Marion Island in the Indian Ocean (Bloomer & Bester 1992), in Australia (Risbey *et al* 1997), and on the Kerguelen and the San Cristobal Islands (Courchamp & Sugihara 1999). In Israel, there is a high probability that free-roaming and feral cats are responsible for the extinction of the rufous (*Cercotrichas galactotes*), formerly a common bird, and the extinction of a subspecies of the green lizard (*Lacerata trilineata israelica*) endemic to Israel, as well as endangering the wild cat (*Felis silvestris libyca*) to the threat of extinction (Mendelssohn 1992). Despite the above, the overall effect of free-roaming urban cats on wildlife is still unclear. Because of the small number of wild animals and the abundance of alternative food, hunting appears to play only a small role in food acquisition (Patronek 1998).

## Regulation of free-roaming cat populations: methods and implications

Methods of regulating free-roaming cat populations can be divided into two general strategies:

### *Eradication*

This strategy can be subdivided into: short-term (generally undertaken when an area is affected by rabies and it is necessary to swiftly curtail spread of the disease); and long-term (undertaken when the cats become a nuisance and the authorities are interested in permanently eradicating them; Remfry 1981). Eradicating or reducing cat populations can be achieved through a variety of methods, such as the introduction of cat-specific viruses (Howell 1984; Courchamp & Sugihara 1999), poisoning (Short *et al* 1997) and hunting (Bloomer & Bester 1992). However, the most common and humane method used against street cats is that of 'trap and euthanasia' (Kristensen 1981; Mahlow & Slater 1996).

### *Reproductive regulation*

This strategy employs two main methods. The first is surgical sterilisation ('trap–neuter–release'). The sterilisation procedure can be performed in two different ways: either ovariohysterectomy in females and orchiectomy in males, which is the most prevalent method (Natoli 1994); or tubal ligation in females (Xemar & Pontier 1998) and vasectomy in males (Mahlow & Slater 1996). Such surgery can be performed from the age of six weeks (Mahlow & Slater 1996). In order to avoid recapture of already-neutered cats, it is customary to mark them by removing the tip of one ear, usually the left (Cuffe *et al* 1983).

The second method is non-surgical sterilisation, including pills to interrupt pregnancy (prolactin inhibitors, eg Cabaergoline). The medication can be introduced into food eaten by free-roaming cats. Prolactin inhibitors are given in the second half of pregnancy, dissolved in a fatty base to help disguise the odour and taste of the active ingredients and thus make them more palatable to the cats (Jochle & Jochle 1993). In addition to this anti-prolactin drug, it is possible to use magestrole acetate, a synthetic form of progesterone, which prevents pregnancy and is also given orally (Remfry 1978). However, it is not authorised (in the USA) for use in cats because it causes severe side effects, particularly diabetes mellitus and mammary cancer (Mahlow & Slater 1996).

**Poisoning**

Research carried out in a nature reserve in Australia examined the effect of poisoning on feral cats that were threatening wildlife in the reserve to the point of extinction. Grains of wheat soaked in sodium monofluoroacetate (1080; see Eason & Frampton 1991), were introduced into the throats of frozen mice which were then placed in various locations throughout the nature reserve. A total of 58 per cent of the bait was taken by the cats. During the nights preceding and following laying of the bait, the number of cats in the reserve was counted. Immediately following the poisoning, a 74 per cent reduction in the number of cats was found and, 18 months later, cat density in the reserve was still only one third of that prior to the poisoning campaign. The reason for the significant decline in size of the cat population lay in the choice of bait and the timing. The bait was laid during a time of relative scarcity of food — the period following two litters, when competition over resources is greater. The study lasted seven years, during which time it was shown that only if over 40 per cent of the poisoned bait was eaten by the cats would a significant decrease in the cat population result. Some of the poisoned bait was eaten by other animals for which the poison was not intended, such as parrots, or by foxes and other predators (the type of animals eating the bait was determined from the tracks found near the bait sites; Short *et al* 1997). To the best of our knowledge, there is no published research that examines the effect of poisoning on street cat populations, despite evidence of the use of this approach, at least in Israel.

***Advantages***

1) Fast and easy to carry out, without the need to trap the cats.
2) Both costs and manpower are relatively low.

***Disadvantages***

1) Cats that eat poisoned food can experience severe agony before death occurs. Because the symptoms vary according to the type of poison used and the amount eaten, we give two examples:
a) Sodium monofluoroacetate (1080): this can cause disorientation, uncoordinated movements, occasional vocalisation, vomiting and several hours of lethargy and immobility before death. Death occurs within 24 h when given at the highest dose of 1.6 mg per bait (Eason & Frampton 1991).
b) α-chloralose: this can cause tonic convulsions, hyperaesthesia, aggression, hyperthermia, prostration and coma (Foster 1995).
2) The scattered poison or poisoned bait may be consumed by other animals in the neighbourhood of the target cats (Short *et al* 1997). It is therefore necessary to monitor the animals taking the poison, remove the bodies of dead animals and remove any remaining poison from the area at the end of the campaign.

3) Poisoning eliminates specimens from the targeted ecological niche, creating a 'vacuum effect'. The resulting vacuum is subsequently occupied by the same number of new individuals as those previously inhabiting the area, thus increasing migration among the cat population without permanently reducing its numbers. It thus offers only a short-term solution (Zaunbrecher 1993). The above study nonetheless found that only one third of the original population remained 18 months following the poisoning campaign (Short *et al* 1997).

In addition to the above, the following disadvantages are relevant mainly in cities:
4) There are still some ethical questions to answer before we consider eradication of free-roaming cat populations merely on the basis of their constituting a nuisance or potential nuisance for human society.
5) The resulting numerous new specimens that enter a population increase the struggle for territory and dominance and the spread of disease vectors. Consequently, the nuisance level will become greater than it was before (Zaunbrecher 1993).
6) Eliminating cat populations being fed on a permanent basis by cat-lovers causes aggravation, distress and sadness to such individuals and leads to their non-cooperation with the authorities (Mahlow & Slater 1996).

**Infectious agents**

In 1948, six pet cats were introduced onto the cat-free Marion Island, Indian Ocean (46°54'S, 37°45'E). In 1977, the feral cat population was estimated at 3405 cats (mean density of 10.8 cats per $km^2$). These feral cats became extremely detrimental to the local bird populations, and an attempt at biological control took place in the years 1977–1982 (Howell 1984; Bloomer & Bester 1992). Because of the unique circumstances (six common ancestors to the whole population), the cat population was examined and the apparent absence of infectious diseases was confirmed by checking carcasses. The absence of feline panleukopenia antibodies was also determined by serology assay. Feline panleukopenia is considered to be a highly infectious and common disease among urban cat populations, making its absence among the Marion Island population unique. Ninety-three cats were trapped, injected intraperitoneally with 1 ml of the panleukopenia virus suspension, and released at different points on the island (Howell 1984). By 1982, the feral cat population had decreased to $615 \pm 107$. However, later evidence suggested that biological control was becoming ineffective (Bloomer & Bester 1992). Because feline panleukopenia virus was only partly successful as a means of biological control, two retroviruses — feline immunodeficiency virus (FIV) and feline leukemia virus (FeLV) — were suggested by Courchamp and Sugihara (1999).

***Advantages***
1) The introduction of infectious agents requires trapping only part of the cat population.
2) Both cost and manpower are low, but become higher during the intensive preparation period prior to applying the method.

***Disadvantages***
1) The effect of the infectious agents on the cats includes their suffering from the disease until death occurs.
2) Application of the method is restricted to an area where other animals (eg pet cats and wild cats) cannot be affected. Thus, this method is inapplicable near human-populated areas

and requires serious consideration of the ecological effect of a candidate agent on the local wildlife.
3) Some of the cats infected with the disease will not die but will acquire immunity to the infecting agent; this immunity may be transmitted to the offspring by an immune mother. With time, the epidemiological nature of the disease will approach stability and become endemic rather than epidemic. Although this can happen in the case of panleukopenia (Howell 1984), it will not occur with retroviruses.
4) This method requires much preparation, such as selecting an infecting agent that is new to the target cat population, ensuring that the agent will not affect local wildlife or pet cats, and selecting a low to moderately virulent virus with a suitable means of transmission.

### Hunting

After using infectious agents on Marion Island, Indian Ocean, for several years (1977–1982), the biological control became ineffective and hunting was used from 1986 to 1990. Hunting was carried out mainly at night by four to eight teams of two hunters each. A total of 14,725 man-hours were involved in 4486 hunting trips. 872 cats were shot dead and an additional 80 were trapped. A further 344 cats were wounded, of which 50 per cent were estimated to have died later. The aim of that program was to eradicate the feral cat population from the island, but because reliable population estimations before and during its implementation were absent, there is no clear assessment of the hunting effect. However, as the number of cats sighted per hour during hunting at night is considered to be the most reliable index of density, the decrease found in sightings per hour served as a measure of the population decline. Trapping together with hunting became a more effective technique than hunting alone after initial reduction of the population size allowed individual cats to be targeted (Bloomer & Bester 1992). To the best of our knowledge, there are no published data relating to the effect of hunting on street cat populations.

#### *Advantages*
1) There is no need to catch the cats nor to approach them.
2) Cost is relatively low.

#### *Disadvantages*
1) The method can be considered inhumane, especially because of the stress and suffering of the wounded cats. The above research, for example, notes 344 (28.29%) wounded cats out of 1216 (344 + 872) that had been shot.
2) The method is inapplicable in urban areas or near human-populated areas because of the hazard to the public.
3) Hunting programs can be very time-consuming and labour-intensive, especially when removing the last individuals.
4) 'Vacuum effect' (see 'Poisoning', above).

### Trap and euthanasia

The method of trapping and euthanasing non-socialised street cats while offering socialised ones for adoption has been carried out in the USA for a number of decades. Surveys undertaken in shelters for free-roaming animals between 1985 to 1992 have led to the conclusion that this method does not solve the problem of street cats. The results of these surveys showed no specific indication of a decline in the number of euthanased or adopted

cats (average of 6.32 ± 1.61 million euthanased cats and 1.71 ± 0.5 million adopted cats each year between 1985 to 1992; Mahlow & Slater 1996).

***Advantages***

1) Among the methods used to eliminate free-roaming cats, this is considered the most humane, as the suffering experienced by the cats is minimal.
2) Selected individuals can be humanely killed in this way without harming other individuals or species.

***Disadvantages***

1) High cost in the time and effort required to catch the cats.
2) It is impossible to trap every free-roaming cat. Those remaining will continue to reproduce and eventually repopulate the area (Remfry 1981; Mahlow & Slater 1996). Achieving a high percentage of trapping is very time-consuming.
3) 'Vacuum effect' (see 'Poisoning', above).
4) Alienation of cat lovers (see 'Poisoning', above).
5) Intensive use of control methods, including capturing the cats, can lead to positive selection for 'wildness' in some feral cat populations. Cats that are trap-shy or fearful of man will continue to roam free and remain fertile. Because these 'wildness' traits are adaptive and are partially learned and partially inherited, in the long term these populations will become progressively less amenable to socialisation (Bradshaw *et al* 1999).
6) Ethical questions (see 'Poisoning', above).

**Trap–neuter (gonadectomy)–release**

A study carried out on a population of free-roaming cats in a demographically isolated hospital ground in the State of Louisiana, USA, examined the effect of applying the trap–neuter–release method to this cat population. The study began with announcements within the hospital of the experiment (in order to gain cooperation from the local staff). Two feeding stations were established from where observations were carried out. The female cats were ovariectomised and the males vasectomised. The tip of the left ear was removed in order to identify the neutered cats. At the beginning of the experiment, 44 cats were observed. From the initial count until sterilisation procedures began, three individuals died, and an additional individual died during the anaesthetic procedure. Of the 40 remaining individuals, two males were not trapped and therefore not sterilised. In the 36 months following onset of the experiment, five cats died and five additional ones disappeared from the area and were assumed to have died. After this period, an additional count revealed 30 of the 40 individuals observed at the beginning of the experiment, as well as six cats new to the area. Thus, at the end of the study period, the cat population was smaller and less reproductive than at the beginning. During this period, a significant improvement in the cats' health could be discerned. This improvement appears to have resulted from better nutrition, a decrease in territorial and sexual behaviours, and a decline in the need to fight for nutritional resources. Although the noise level produced by the cat population was not scientifically measured, there were reports of a significant decrease in noise level, particularly at night (Zaunbrecher 1993).

An additional study, carried out in Regent's Park, London, monitored two small groups of cats (seven adult cats and nine adult cats) that were fed daily at two locations in the park. After one month of preliminary observations the cats were trapped, neutered and returned to the trapping site. Following sterilisation, the frequency of appearance of the males at the

feeding sites increased, and the cats spent longer periods of time there. Increased positive interaction was observed among individuals in the group and the cats also became more friendly to humans. This treatment of cat populations that had become a nuisance to the park authorities (who suspected that the cats were preying on some of the ducks and geese in the park) provided an acceptable solution to these authorities: it enabled control of population size, as no more young were born following the sterilisation procedures; and no further predatory acts by the cats on the exotic wildlife in the park were observed (Neville & Remfry 1984).

Another study, at a hospital in England, was carried out during 1977–1980 in two stages: observations of the cat population for 12 months, and sterilisation of the majority of the cats followed by observation for a further 12 months. From a comparison of the number of cats counted before and after sterilisation, it can be seen that the population stabilised in both number and composition throughout the year following sterilisation (Rees 1981). It was found that, during the period prior to sterilisation, the males held significantly larger home ranges than the females. No such difference was found in the period following sterilisation. During the latter period, groups of cats became more stable because of the decrease in the number of males wandering between groups and the increase in the number of males permanently joining a particular group. Fewer cats disappeared from the study area in the year following sterilisation (Rees 1981).

***Advantages***

1) The method is irreversible, thus necessitating trapping each cat only once and marking it to avoid retreatment (Cuffe *et al* 1983).
2) Gonadectomy leads to hormonal and behavioural changes in the cats (Mahlow & Slater 1996) and a consequent reduction in the odour and noise nuisance generated by a dense cat population (Remfry 1981).
3) These hormonal and behavioural changes reduce negative and sexual interactions among individuals (Neville & Remfry 1984; Brown & Bradshaw 1996). Such interactions can lead to injury as well as the spread of parasites and diseases (Fromont *et al* 1997; Kerby & Macdonald 1988). Therefore, we can assume that the chances of spreading diseases and parasites as well as of injury will be decreased in a gonadectomised cat population.
4) Gonadectomy in pet cats leads to a decreased metabolic level, decreased activity level and increased food consumption, which in turn leads to increased body weight (Flynn *et al* 1996; Fettman *et al* 1997). It is highly probable that a similar effect is found in street cats, thus also contributing to an improved general physical condition.
5) Because of the humane nature of this method, it is possible to obtain the cooperation of those feeding the cats in trapping them (Remfry 1981). In addition, where the cats' presence is desired by those around (also as 'rodent exterminators'), the cat population that is returned following neutering will be welcome (Mahlow & Slater 1996).
6) Studies have shown that the mean age at death of neutered cats is greater than that of intact cats (in Boston, a two- to three-fold difference was found; Bronson 1981; Robinson 1992).
7) The above-mentioned hormonal changes in turn also lead to behavioural changes (Mahlow & Slater 1996). Tabor (1981), referring to the behaviour of cat groups in London that had been neutered several years previously, noted that these groups appeared to maintain their intra-group social behaviour and prevented the entry of strange cats into their territory. The long-term effect on social structure, social composition and migration of populations subjected to this method remains to be studied.

***Disadvantages***

1) Although it appears that neutering is more humane than eradication, there are those who claim that preventing reproduction has a greater negative effect on animal welfare than destroying the animals.
2) Difficulty in catching all free-roaming cats (see 'Trap and euthanasia', above).
3) Releasing the neutered cats back to the area from which they were taken does not prevent some of the nuisance factors that the public complain about, for example hygiene, public health and predation on wild animals (Mahlow & Slater 1996).
4) Both manpower and cost are very high.
5) Positive selection for 'wildness' (see 'Trap and euthanasia', above).

**Trap–sterilisation (vasectomy/tubal ligation)–release**

In a study carried out in 1995 in an urban environment in France, 292 cats were trapped and neutered out of a total of 382 individuals forming 33 different groups. Each group underwent sterilisation by either gonadectomy or tubal ligation in females and by vasectomy in males. Average percentage sterilisation in the groups was 75.2 ± 16 per cent (range 40–100%). Six months after trapping and sterilisation, population size had risen by 12.3 per cent. The increase in group size was significantly higher in the groups subjected to gonadectomy than in the groups undergoing ligation (22% and 1.6%, respectively). Groups in which 100 per cent of females were sterilised (using either method) showed a decrease of about 30 per cent in population size after six months (Xemar & Pontier 1998). According to our experience in the field, a possible explanation for the increase in group size after sterilisation is the fertility of the remaining non-sterile queens and the migration of neighbouring cats. Furthermore, because gonadectomised cats present less aggressive behaviour than intact ones (Neville & Remfry 1984), we can assume that a similar difference in behaviour occurs between gonadectomised and vasectomised cats. Aggressive behaviour can affect the migration rate of neighbouring cats, which explains the difference in increased group size of gonadectomised compared to vasectomised cats (22% and 1.6%, respectively).

Residents in the study area were surveyed before and after sterilisation of the cat population. A significant difference was found for the two periods: prior to sterilisation, 17 per cent of residents desired the presence of cats, 32 per cent were indifferent, and 51 per cent did not want them; following sterilisation, 44 per cent desired the presence of cats, 31 per cent were indifferent, and 25 per cent did not want them. No significant difference was found in the survey among the various sites regarding the different methods of sterilisation, despite the noise nuisance factor decreasing more in groups subjected to gonadectomy. The odour nuisance factor remained in all groups (Xemar & Pontier 1998).

***Advantages***

1) Each cat is trapped only once (see 'Trap–neuter [gonadectomy]–release', above).
2) Neither vasectomy in males nor tubal ligation in females leads to hormonal changes, as the gonads remain functional. No short-term behavioural changes are thus expected in cats that have undergone sterilisation. Consequently, continuation of normal behaviour in the population will prevent changes in social structure, particularly hierarchy. The males will continue to guard their territory, fight for their right to copulate with the females that continue to come into heat, and prevent the entry of new individuals into the group (Kendall 1979; Natoli 1994; Xemar & Pontier 1998). On the other hand, it is likely that vasectomy and tubal ligation will lead to long-term changes in the social behaviour of the group because females do not become pregnant, a consequence that can affect fighting between males.

3) Cooperation of cat-lovers (see 'Trap–neuter [gonadectomy]–release', above).

***Disadvantages***

1) Negative effect on animal welfare (see 'Trap–neuter [gonadectomy]–release', above).
2) Difficulty of catching all free-roaming cats (see 'Trap and euthanasia', above).
3) Some of the nuisance remains (see 'Trap–neuter [gonadectomy]–release', above). In addition, this method does not lessen noise or odour (Natoli 1994; Xemar & Pontier 1998).
4) Both cost and manpower are very high.
5) Positive selection for 'wildness' (see 'Trap and euthanasia', above).

**Non-surgical sterilisation**

In a study carried out over six years in an open rural area in New Jersey, USA, involving almost daily observations, the effect of the prolactin inhibitor Cabergoline on a group of cats comprising 12 females and 13 males was examined. The cats were fed dry food *ad libitum* and canned cat food twice daily. The observed reproduction pattern over one year revealed that 80 per cent of oestrus occurred during the first half of the year and the number of pregnancies rose during the second quarter of the year. Out of the total number of pregnancies recognised during the study period (n = 48), seven were deliberately not inhibited; and out of the 22 young born, 16 (73%) reached the age of six months. The drug was usually given in mid-pregnancy (days 25–48, average 36.1), for an average of 4.9 days. The first effect observed was a reduction in the size of the mammary glands (within 36–48 h), followed by abortion (days 34–53, average 40.5) in every case. In the minority of cases in which the drug was given at a more advanced stage of pregnancy (days 44–56, average 48.2), live young were born and died shortly after birth because of the mother's inability to produce milk as a result of prolactin inhibition. The females that either aborted or underwent premature delivery returned to oestrus after an average of 6.13 or 9.5 days, respectively (Jochle & Jochle 1993).

Treating pregnant cats by means of anti-prolactin accelerated the latency to abortion in all cases, generally within 3–5 days from the start of treatment. Previous studies by the same researchers revealed that treating pregnant cats prior to day 30 of pregnancy did not result in abortion.

In order to prevent feline pregnancy, the drug Cabergoline should be introduced at fortnightly intervals into the food eaten by the target population. In places where reproduction is restricted to a few months of the year (Jochle & Jochle 1993), it is sufficient to treat during those months only. In warmer regions, however, where reproduction takes place throughout the year, treatment must be continuous (W Jochle, personal communication, August 1999). It is assumed that the drug will also be accessible to other animals, upon which its effects are not known. Therefore, it may be practical to introduce the drug into food at feeding stations accessible mainly to free-roaming cats and dogs (the drug is also intended for use in dogs) in urban and suburban areas (Jochle & Jochle 1993).

Recent publications have reported on inoculation of a recombinant vaccine against the zona pellucida. This once-only vaccination, administered to females that have not yet reached sexual maturity, prevents spermatozoa from penetrating the ovum and offers life-long protection. In addition, the use of epididymal sclerosing agents has been studied in males, thereby preventing male fertility without affecting the normal testosterone levels. (Mahlow & Slater 1996). Furthermore, a chemical sterilant currently holding promise for use in males is zinc gluconate neutralised by arginine. Its injection into the testes or the epididymides

induces sterility without interfering with the development of male secondary sexual characteristics (Bloomberg 1996). These materials may offer a cheaper solution and enable speedier sterilisation of street cat populations (Mahlow & Slater 1996). Because the vaccinations described in this paragraph require trapping the cats, these methods lack the advantage of preventing reproduction without the need to trap the individuals.

***Advantages***

1) It is not necessary to trap the cats in order to control their reproduction, facilitating reproductive control over all the females in the treated population.
2) The medication (as advised in Jochle & Jochle 1993) is reliable and produces no side effects, in comparison with the recovery period required following surgical sterilisation of females (Jochle & Jochle 1993).
3) Cat populations treated by means of prolactin inhibitors retain normal behaviour patterns, and the females continue to come into heat (Mahlow & Slater 1996).
4) Time effort is relatively low.

***Disadvantages***

1) Negative effect on animal welfare (see Trap–neuter [gonadectomy]–release, above).
2) The medication is expensive, making this method costly to operate (W Jochle, personal communication, August 1999).
3) To achieve effective treatment it must be given at fortnightly intervals throughout the year (in Israel), or throughout the entire period requiring reproductive control of the cat population. Upon terminating treatment, the cats return to fertility (Jochle & Jochle 1993).
4) Medication is given to all individuals in the population because it is not possible to direct the treated food at the females alone. Consequently, the amount distributed in order to prevent pregnancy will be larger than the amount needed for the number of cats actually requiring treatment.
5) Long-term treatment requires regular distribution of the medication by individuals or authorities interested in controlling cat reproduction, and is therefore restricted in use to cat populations being fed on a regular daily basis. Cats not fed in this way but seeking their own food cannot be treated using this method (Remfry 1981).
6) Although such treatment prevents fertility, it does not lessen the noise or odour levels created by high-density cat populations (as detailed in 'Positive and negative aspects of the presence of free-roaming cats in an urban environment'), as the females continue to come into heat and the males continue to fight among themselves for the right to copulate.

## Conclusions

The above-mentioned methods of control (see Table 1) deal with just one aspect of the free-roaming cat problem — management of street cats only. In order to reduce a street cat population, or maintain it at a stable level, it is necessary to deal with the factors that create and enhance these populations. Solutions that rely solely on treating the street cat population, but do not deal with abandoned pet cats or the contribution of offspring of such cats that leave the home environment, will be partial solutions at best. Settling for such partial solutions will necessitate the responsible bodies continuing to treat the street cat populations on a permanent basis. The answer, therefore, lies in the application of a combined method.

The method used to deal with street cats should primarily be chosen according to the aim required (eradication or reproductive regulation of cat populations). When determining the aim, it should also be borne in mind that there are positive aspects to the presence of street

cats, and that the chances of successful treatment depend upon cooperation of the public in general and of cat-feeders in particular. The method of treatment should then be suited to the entire group of cats — fed street cats, non-fed street cats and pet cats.

**Table 1 Summary of the advantages and disadvantages of the regulating methods.**

| Management strategy | Method | Accessibility of treatment to free-roaming cats | Cost and manpower | Specificity of treatment | Probability of creating vacuum effect | Probability of obtaining cooperation of feeders and cat lovers | Is the treatment considered to be humane? |
|---|---|---|---|---|---|---|---|
| Eradication | Poisoning | Good access when using baits | Both relatively low | Low, but can be improved using the recommendations noted in disadvantage no.1 under 'poisoning' | High | Very low | No |
| | Hunting | Good access | Manpower is high, cost is relatively low | Medium | High | Very low | No |
| | Infecting agents | Accessibility depends on pathogenicity and virulance of the agent | Proper use of method requires intensive preparation, so cost and man-power high | Very low | High | Very low | No |
| | Trap and euthanasia | Poor accessibility because of the need to trap the cats | Both relatively high | High | High | Low | Opinions differ |
| Reproductive regulation | Trap–neuter (gonadec-tomy)–release | Poor accessibility because of the need to trap the cats | Both relatively high | High | Low | High | Yes |
| | Trap–neuter (vasectomy/ tubal ligation)–release | Poor accessibility because of the need to trap the cats | Both relatively high | High | Low | High | Yes |
| | Non-surgical sterilisation | Accessibility good when dealing with regularly fed cats and poor when dealing with non-fed cats | Manpower is low but cost is high | Low | Low | High | Yes |

For the reasons set out below, the conclusions drawn from this survey regarding the most appropriate method for regulation of street cat populations in Israel are not clear-cut, and additional fieldwork is required in order to determine the best strategy for each target population.

1) Some of the studies were based on areas with a cold climate. However, the warmer the weather, the greater will be number of oestrous cycles per year, with continuous cycling throughout the year in tropical regions of the world. Furthermore, the chances of cat survival decrease in correlation with colder and longer winters, reducing the cat population without intervention by man.

2) Some of the studies were based on isolated rural or unsettled areas (Rees 1981; Jochle & Jochle 1993; Zaunbrecher 1993; Short *et al* 1997). Therefore, conclusions cannot be drawn from those studies regarding urban areas, in which cat density is far greater.
3) Some of the studies examined only small groups of free-roaming cats (Neville & Remfry 1984) or were carried out without controls (Jochle & Jochle 1993; Zaunbrecher 1993; Short *et al* 1997; Xemar & Pontier 1998) and thus do not determine whether any change did in fact result from the method of treatment. In addition, even if the treatment was responsible for the change, its significance could not be assessed without comparison with a non-treated group.
4) The majority of studies were short-term only and did not examine the long-term effect of the treatment.

Despite the fact that many questions still remain to be answered regarding the effectiveness of the various methods of treatment, there is nonetheless a new trend in various parts of Europe and the USA toward ceasing the eradication of street cat populations and employing the 'trap–neuter–mark–release' method instead. Methods of eliminating street cats are prevalent mainly when the animals pose a clear danger to wildlife, threatening extinction of species as a result of predation by feral cats, or when there is the threat of zoonotic disease transmitted by street cats. These methods are carried out in designated areas only.

In light of the above information, and despite the many questions still remaining regarding the effectiveness and means of application of the various methods of controlling cat populations in Israel, we set out below our recommendations regarding street cat populations in Israel. We take into consideration the ethical questions involved in selecting a method of population control and the unique combination of factors influencing the free-roaming cat populations in Israel:
a) Warm climate, enabling more oestrous cycles and higher survival rates.
b) Relative lack of public responsibility toward animals, as expressed in the high number of abandoned pets and low number of neutered ones.
c) General funding problem, which is the outcome of the political and defence priorities. Consequently, relatively small amounts of money are invested in issues such as conservation, animal welfare and education of the public in these aspects.
d) High-density human population in Israel leads to vast urban areas that contain an abundance of food resources (from feeders and garbage).
e) A law for the prevention of cruelty to animals was finally enacted only in 1994. There are still no regulations that relate to licensing and marking of pet cats. Therefore, enforcing the prevention of abandonment of cats is almost impossible.
f) The current regulations relating to the management of free-roaming cats mainly deal with specific complaints by the public and do not refer to population management, except when a defined area is declared to be infected with rabies. Furthermore, the risk of transmitting zoonoses and rabies in particular is the main reason for the authorities' willingness to eradicate free-roaming cat populations.

***Recommendations***

Because eradication methods that employ hunting, infecting agents or poisoning cause great agony to the cats, and because of the hazards to the public and surroundings (see disadvantages of these methods), we strongly disapprove of such methods in an urban environment. As a long-term strategy, the method of trap–neuter–mark–release should be adopted, in parallel with keeping garbage cans securely closed (reduction of vital resources) and dealing with specific complaints. Sterilisation (hysterectomy/gonadectomy or tubal ligation/vasectomy) as the method of choice should be appraised according to the

environment inhabited by the cats and the expertise of the veterinary surgeons. Sterilisation by means of medication is recommended in cases where there is organised supervision and monitoring of a specific cat group; here too, however, it is necessary to examine the long-term effect of this sterilisation on the numerical and compositional stability of the treated group. Use of methods to eradicate cat populations, particularly the method of trap–euthanasia, is recommended mainly in the case of individuals whose poor physical condition justifies euthanasia. In addition, it is necessary for public information and education campaigns to be undertaken, for the benefit of pet cat owners whose pets also roam the streets, regarding the need both to mark their cats and to neuter them.

## Acknowledgments

We greatly acknowledge the help of Ms N Pas in translating and editing this manuscript. This study was supported by 'The Animal Fund' at the Israel Ministry of the Environment.

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