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Ecology of a feral cat *Felis catus* population in an agricultural area of northern Italy

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The ecology of a feral cat population in an intensively cultivated region of northern Italy was studied. The study area is a land accretion territory, reclaimed in the early 1970s, characterised by the absence of any food source of human origin (e.g. garbage dumps, farms, houses) and surrounded by a continuous irrigation channel that is likely to limit immigration/emigration of cats. The cat population was censused for two successive years using the sighting-resighting method; spacing patterns were studied by means of radio-telemetry; hunting behaviour was assessed by observation. Feral cats avoided any direct contact with humans, and reproduced in the wild. The density of the population remained stable throughout the study period. Turnover appeared very high, and was remarkably higher than that of cats regularly fed by humans. Very low densities, large home range sizes, solitary habits, territorial patterns similar to those of the wildcat, seasonal parturition, and prevalence of hunting activity were found. We speculate that these patterns are related to the peculiar conditions of resource availability and dispersion in the study area. Our results indicate that feral cats, even in agricultural areas and in the absence of any food provided by humans, have solitary habits and low densities, thus confirming a key role of resource availability and dispersion on the ecology of carnivores.

Key words: Feral cat, Felis catus, census, density, home range, habitat selection, social organisation

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In recent years, much attention has been given to the ecology of free-roaming domestic cats *Felis catus* for the following reasons: 1) predation by cats on species of conservational interest or economic value (e.g. George 1974, van Aarde 1980, Fitzgerald 1988); 2) social and sanitary problems arising from the presence of abundant feral cat communities in contact with humans (Rees 1981, Southam 1981); 3) the threat of transmission of pathologies both to wild and domestic animals (Nicholson 1981).

The domestic cats can be dependent on humans or rely completely on natural food sources. In fact, large variations in population parameters and social patterns have been found (see review in Liberg & Sandell 1988), and the abundance and dispersion of food resources appear to be the main factors of influence. In areas where food resources are abundant and clumped (e.g. in urban areas, market areas, garbage disposals), cat densities may be higher than 2000 individuals/km^2, and are generally higher than 50 individuals/km^2 (Dards 1978, 1981, Natoli & De Vito 1988). Where resources are dispersed and of more natural origin (as in the forests and rural areas of Europe), and where cats are fed by humans (farms or country houses) to some extent, the density varies between 5 and 50 individuals/km^2 (Liberg 1980, Macdonald & Apps 1978). In general, the density of cats relying on dispersed resources of non-human origin is below 5 individuals/km^2 (Liberg & Sandell 1988), not much different from that of the wildcat *Felis silvestris* which is 0.3-0.5 individuals/km^2 (Stahl 1986). Resource availability also affects the social organisation of domestic cats. When food resources are abundant and/or clumped, females form stable groups (generally kin), and males move between groups of females. When resources are dispersed and/or scarce, both females and males live solitarily (Liberg & Sandell 1988).

The present study was conducted on a feral cat population living in an agricultural area of northern Italy. The area, a land accretion territory reclaimed in the 1970s (and thus only recently colonised by cats), has no garbage dumps and no human settlements. This implies complete absence of artificial food sources for the cats, and we thus assume that resources are dispersed and less abundant than in urban areas or farms. The area is surrounded by an irrigation channel which likely limits immigration or emigration by cats. The objectives of our study were: 1) to estimate the density of the feral cat population and to evaluate the effectiveness of a census method for cat populations in rural areas; 2) to estimate home range sizes and overlaps; 3) to describe the activities of feral cats, notably their hunting behaviour.

Study area

The study was carried out from January 1994 to June 1995 in an area of 4,168 ha placed centrally in the 17,000-ha land accretion area of the 'Mezzano', originally part of the lagoon complex of Comacchio (the Po Delta region), and reclaimed in the early 1970s (Fig. 1). A continuous irrigation channel (width ≅ 30 m), crossed by few bridges (<10), surrounds the whole area and thus constitutes a limit to natural immigration or emigration of cats. Yearly average temperature is 13.5°C, with maximum 23.6°C in August and minimum 1.5°C in January. Yearly average rainfall is 726.1 mm, with most falling in autumn and least falling in winter. The topography of the area is flat and the altitude lies between 5 and -5 m a.s.l. The area is intensively cultivated and there are many irrigation channels where redbeds *Phragmites* sp. are common; the only arboreal vegetation are shelter belt plantations of elm *Ulmus pumila*, aspen *Populus alba*, locust *Robinia pseudoacacia* and tamarisk *Tamarix* sp. Cultivated fields cover 92.1% of the area, meadows 3.5%, shelter belts 1.8%, irrigation channels 1.2%, roads 0.8%, drain channels 0.5%, and reed thicket 0.1%.

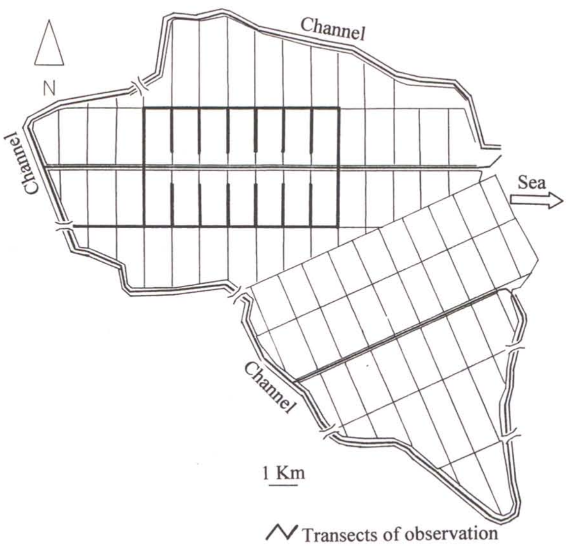

Figure 1. The study area surrounded by a continuous irrigation channel, crossed by few bridges. The observation transect (37.5 km) crossed three times in each day-session during the census is indicated with bold lines.

No farms or houses were present within the study area; the only buildings were 50 sheds for farm tractors, in some of which farmers keep and feed domestic cats (shed-cats), in order to control rodents. Since the land accretion, several species of carnivores have colonised the area: e.g. weasel *Mustela nivalis*, fox *Vulpes vulpes*, and badger *Meles meles*.

Material and methods

We use the following definitions according to Liberg & Sandell (1988): 'feral cat' is a domestic cat that is not attached to a particular household; 'house-cat' is a cat that lives in close connection with a household. 'Shed-cats' are cats living in sheds and fed by farmers.

We assessed population density by censusing shed-cats and feral cats (Liberg 1982). To census cats inhabiting the sheds, we interviewed all shed owners and recorded the total number of cats, their sex and parturition events. All shed-cats were then photographed for individual identification. To census the feral cat population we used a sighting-identifying-resighting procedure developed from capture-mark-recapture techniques (Beck 1982, Liberg 1982). Within the study area we crossed a transect of 37.5 km three times per day (≅112.5 km/day-session), homogeneously covering the study area (see Fig. 1). We carried out 18 day-sessions in 1994 (January-March) and 20 in 1995 (November-March), recording all sightings of cats (131 in 1994, 106 in 1995). When sighted for the first time, the cat was photographed using long focal lenses (Nikkor 1000 1:11), and morphological and coat characters were recorded (Apps 1983). Sighting data were analysed using the Schumacher-Eschmeyer method (Seber 1982: pp.141-142): in each session (t) the number of individuals previously marked (M_t) and the proportion of marked individuals in the session (R_t/C_t; R_t = number of individuals already marked when caught in sample t, C_t = total number of individuals caught in sample t) allow us to estimate, using linear regression, the population size by the formula:

$$\hat{N} = \frac{\sum_{t=1}^{s} (C_t / M_t^2)}{\sum_{t=1}^{s} (R_t M_t)}$$

where s is the total number of sessions.

The procedure allows us to calculate variance and standard error, and thus to obtain confidence intervals. This method assumes a closed population (Krebs 1989); we did not consider this assumption violated since censuses were performed within a short period of time, which is in accordance with Krebs's (1989: p. 27) suggestions. Based on the total sample of sightings, we calculated the proportion of non-identifiable cats in order to correct the estimate obtained from sighting-resighting.

The home range was studied by means of radio-telemetry. Animals were caught in cage traps baited with game flesh, anesthesised with ketamine (Ketalar Parke-Davis, 0,10-0,15 cc/kg), sexed, and classified as adults/subadults by the wearing of teeth. Seven cats were fitted with radio-collars (AVM), and localised at all hours of the day. To avoid autocorrelation errors (Swihart & Slade 1985), we accepted a minimum time lapse of six hours between consecutive fixes. Cats were extremely shy and tended to run away when we got closer than 100 m; it was thus impossible to carry out continuous radio-tracking sessions. Home range was estimated by 100% Minimum Convex Polygon (Mohr 1947) since we did not register erratic movements. Home range sizes were measured using a Geographic Information System (ARC-INFO, Esri Ca).

We used radio-tracking data to estimate habitat use. Data of all individuals were pooled, and habitat selection was then calculated using the Bonferroni method (Neu et al. 1974). This statistical procedure, which assumes independence of locations, first tests for habitat selection considering all habitats together, then tests for habitat selection for each habitat, allowing the calculation of confidence intervals. The method assumes that habitat availability is measured without error (Alldredge & Ratti 1992); we considered this assumption to be fulfilled, as all habitat types were accurately measured in the field.

To study hunting techniques and social interactions, each sighted individual was observed for as long as possible, and associations, interactions, hunting and other activities were recorded (in total, 1,853 minutes of observation at 318 occurences).

Results

In 1994, 13 shed-cats inhabited 6 of the 50 sheds present in the study area, while we estimated a population of 31.1 feral cats (95% conf. lim.: 24.4 - 43.1) using the Schumacher-Eschmeyer method (Table 1). The estimate was then corrected by multiplying it by the proportion of non-identifiable cats (39.6%; N = 12.3). The above procedure led us to an estimate of 63.4 individuals (54.0 - 80.2), and a density of 1.5 individuals/km^2 (1.3 - 1.9). In 1995, 18 shed-cats were recorded through interviews. The total population of shed-cats and feral cats consisted of 58.5 individuals (47.0-86.0), with a density of 1.4 individuals/km^2 (1.1 - 2.1). Of the 25 feral cats identified in 1994, only two (8.0%) were resighted in 1995. Of 13 shed-cats identified in 1994, eight (61.5%) were recorded in 1995.

Table 1. Observed and estimated numbers of cats censused in the study area of 4,168 ha during January-March 1994 and November-March 1994-1995. The total population of feral cats is estimated by the Schumacher-Eschmeyer method and corrected by the proportions of non-identifiable cats and radio-collared cats.

	January - March 1994		November - March 1994 - 1995	
	Observed	Estimated	Observed	Estimated
Shed-cats	13		18	
Feral cats	25	31.1	20	23.7
Radio-collared cats	7		1	
Non-identified cats		12.3		15.8
Total population		63.4		58.5
Conf. lim. (95%)		54.0 - 80.2		47.0 - 86.0

Hunting was by far the most frequent activity observed (92.6%), and the cats used hunting strategies such as sit-and-wait and stalking, which are strategies used especially for predation on vertebrates (Turner & Meister 1988). These results, however, should be interpreted with caution, as our data probably are biased: in fact we never observed cats in reed thickets and hardly in arboreal shelter belts, due to the vegetation cover, even though radio-telemetry showed that these two habitats were often used by cats.

Feral cats lived solitarily; association of two or more cats was observed in 4.6% of the cases only, and these were recorded mainly during the mating season.

From January to August 1994, seven adult feral cats (four females and three males) were radio-tracked. Male M32 was accidentally killed during agricultural operations 11 days after capture, and thus its home range should be considered indicative only. Due to low efficiency of transmitters and to the shyness of the cats, we were unable to track these continuously, and in total only 199 locations were recorded. All individuals but one (M41), exclusively used areas where no sheds were present. In the radio-tracking period, which included the breeding season, one male (M2) had a very large home range (Table 2) overlapping those of three females, but only slightly

Table 2. Sex, sample size of radio-locations, periods of radio-tracking and home range sizes (100% Minimum Convex Polygon) of seven feral cats radio-tracked simultaneously during 1994-1995.

Animal	Sex	No of radio locations	Radio-tracking periods	Home range size (ha)
2	M	42	Jan 19 - Apr 21	639
32	M	7	Mar 3 - Mar 14	5
41	M	11	Feb 14 - Jul 18	149
24	F	46	Feb 2 - Jun 19	173
30	F	37	Feb 23 - Jul 20	62
31	F	23	Feb 23 - Apr 21	254
37	F	33	Mar 2 - Jun 8	101

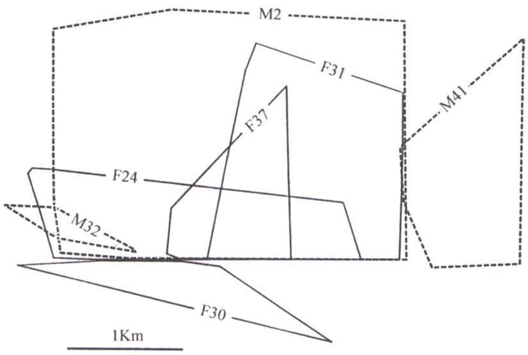

Figure 2. Home ranges (100% Minimum Convex Polygon) of the four female (bold lines) and three male (broken lines) feral cats radio-tracked simultaneously in 1994 and 1995.

overlapping those of two other males (Fig. 2). However, one non-identified cat (probably a male) was observed within the home range of M2. Female home ranges overlapped partly.

Feral cats significantly (Bonferroni correction for multiple testing: all habitat selected ($P < 0.001$)) preferred habitats providing good cover (arboreal shelter belts, reed thickets, vegetation at the edge of drain channels) (Fig.3). Cats often hunted in meadows, while cultivated fields were avoided. A few hay bale heaps present in the area were used as resting sites by three of the seven radio-tracked animals, and thus resulted significantly selected.

Of the four females radio-tracked during the breeding season, parturition was ascertained in two cases when litters of 3 and 5 kittens were located, and in another case a lactating female was retrapped. Parturition occurred in May. The two litters were located on the ground (one in a shelter belt, one in reed thicket) perhaps owing to lack of dens. There were no indications (e.g. lactating females or kittens) of parturitions among feral cats in other periods of the year. We recorded two parturitions among shed-cats, also in May.

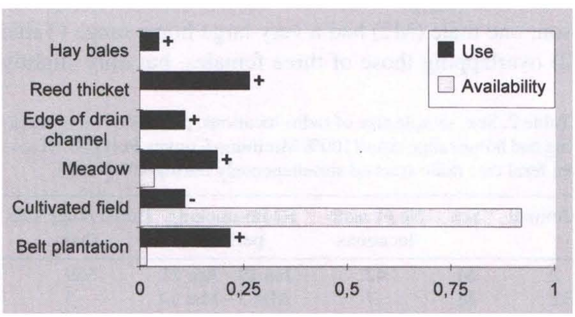

Figure 3. Habitat use of seven feral cats estimated on the basis of radio-locations (N = 301), compared with habitat availability and significance of selection (Bonferroni correction for multiple testing, $P < 0.001$; + indicates significant selection; - indicates significant avoidance).

Discussion

The census procedure adopted in the present study may permit the assessment of feral cat consistence and density in large rural areas, when the cover allows visibility. An advantage of the sighting-resighting estimate, is that it permits the evaluation of confidence limits, although the reliability strongly depends upon the percentage of non-identified individuals. Our results indicate that the best period to census feral cats in mild climates is late winter, when visibility is higher than in any other season (Fig. 4).

Feral cats in the study area avoided any contact with humans and reproduced in the wild. Density estimates were similar in the two winter censuses. The turn-over between the two winter censuses seemed very high, and remarkably higher than for shed-cats. This could indicate a much higher mortality rate among feral cats than among shed-cats, most likely due to both illegal control (in 1994 we collected 25 cats killed in the 'Mezzano') and to a direct dependence on natural resources. Since we found a much lower turn-over for shed-cats than for feral cats, we speculate that the feral population is strongly dependent upon shed-cats, the latter constituting a recruitment source for the former.

The limited sample of fixes used to define home ranges may lead to an underestimation of home range sizes and overlap (Jennrich & Turner 1969). A prudent interpretation of our results is that cats had very large home ranges and that the two sexes overlapped widely.

The low densities, solitary habits, and large home ranges recorded for our study population appear similar to those of feral cat populations living in areas where no food is provided by humans and in areas where resources are widely dispersed (Corbett 1979), and differ from the habits of feral cats in other rural areas of Europe, North America and Australia (Liberg 1980, Warner 1985, Turner & Mertens 1986, review in Liberg & Sandell 1988). This supports the idea that density and social organisation are determined mainly by absolute food abundance and dispersion (Macdonald 1983, Liberg & San-

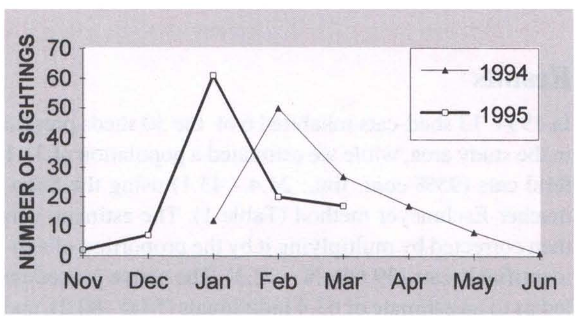

Figure 4. Seasonal variation in observability given as numbers of sightings of feral cats per month in 1994 and 1995.

dell 1988). The recent origin of the 'Mezzano' feral cat population indicates that density and social organisation may shift rapidly from those typical of farm-cats to those of solitary feral cats if the available resources change from being clumped and partly provided by humans, to being dispersed and of non-human origin.

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