Effects of building features on density and flock distribution of feral pigeons *Columba livia* var. *domestica* in an urban environment

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Abstract: We censused feral pigeons (*Columba livia*) living in Milan, Italy (a 181-km^2 area), between July 1999 and February 2000 by means of linear transects to examine population densities in different urban habitats and the relationships between population density and structural features of buildings. The pigeon population of Milan was 103 650 birds, with an average density of 570/km^2. Population density increased significantly from farmland (434 birds/km^2) to the suburbs (604 birds/km^2) and from the suburbs to the centre of the city (2083 birds/km^2). There was a positive relationship between both bird number and flock number and the abundance of buildings constructed before 1936. There were no significant associations between either bird number or flock number and the abundance of buildings when we did not consider date of construction. This indicated active selection of old buildings by feral pigeons.

Résumé : Nous avons recensé les pigeons sauvages (*Columba livia*) de Milan en Italie (une zone de 182 km^2) entre juillet 1999 et février 2000 en établissant des transects linéaires pour examiner la densité des populations dans les divers milieux urbains et déterminer les relations entre la densité et les caractéristiques structurales des édifices. Au moment du recensement, la population de pigeons de Milan comptait 103 650 oiseaux avec une densité moyenne de 570/km^2. La densité des pigeons augmentait des zones agricoles (434 oiseaux/km^2) aux banlieues (604 oiseaux/km^2) et des banlieues au centre-ville (2083 oiseaux/km^2). Nous avons trouvé une corrélation positive entre, d'une part, le nombre d'oiseaux et le nombre de volées et, d'autre part, l'abondance des édifices construits avant 1936. Il n'y avait aucune association significative entre le nombre d'oiseaux et le nombre de volées et l'abondance des édifices lorsqu'on ne tenait pas compte de la date de leur construction, ce qui indique que les pigeons sauvages font un choix délibéré des vieux édifices.

[Traduit par la Rédaction]

Introduction

The earliest observations of feral pigeons in towns date back to 1385 (London) (Johnston and Janiga 1985), although the pigeons did not cause problems for humans until 1930. Since the 1950s, urban populations of feral pigeons have been increasing quickly because of feeding by a benevolent public and greater food availability due to human activities (grain stores, markets, provender plants, etc.).

In most European and North American cities, governments have taken measures against feral pigeons because of the health risk to humans and damage to buildings caused by bird feces.

Fundamental to any program of population control is a thorough understanding of the processes affecting the distribution and density of pigeon populations (Sol and Senar 1995). Although population size is primarily determined by food availability linked to human activity (Murton et al. 1972*a*, 1972*b*; Haag 1987, 1995), the number of pigeons in an urban habitat may be related to the number of people living in the town (Barbieri and De Andreis 1991) and to the density of the human population (Jokimaki and Suhonen 1998). The structure of the town and environmental features could also affect the numbers of birds: highest densities are usually found in the historical centre of towns, while feral pigeons are scarce or absent in urban parks and suburbs (Lancaster and Rees 1979; Luniak 1983; Johnston and Janiga 1985). Since optimal habitat availability can be an important factor influencing population response to control, building selection and use by pigeons are crucial parameters to investigate.

Our objectives were to examine the population density of pigeons in different urban habitats, and the relationships between population density and structural features of buildings.

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Study area

The study was carried out in the city of Milan, Italy (45°28′N, 9°12′S), which comprises 181 km^2 of level ground consisting of 122 km^2 (67%) of buildings, 52 km^2 (29%) of farmland, and 7 km^2 (4%) of urban parks. To the north, one urban area runs into another without interruption, while the farmland (cornfields, rice fields, soya-bean fields, and meadows) is mainly in the suburbs to the south-southeast.

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Several farmsteads devoted to cattle breeding are scattered outside the city.

The climate is continental (average temperature 1°C in winter and 24°C in summer) and precipitation ranges from 80 to 100 cm/year. The overall population is 1 300 000 people (Municipality of Milan 1998).

Architectural features of buildings differ according to the date of construction: bricks and roof tiles (hereinafter "old buildings") generally before World War II and glass and reinforced concrete (hereinafter "new buildings") thereafter. The distribution of the two main architectural types in Milan was strongly influenced by bombing during 1941–1943, which opened several holes in the brick – roof tile part of the city. The Town Plan of the 1930s also altered the original architectural organization of the city by opening new wide streets in the centre and replacing old buildings with new ones.

There is no information about when feral pigeons first appeared in Milan, but feral populations increased rapidly earlier than in other Italian towns because of the great extension of the urban area and the availability of a large number of historical buildings. Indeed, feeding birds was prohibited for the first time by public authority in 1928.

Methods

Preliminary work

The main difficulty in censusing feral pigeons is that many are not visible, so the true population size is larger than is indicated by the figures obtained. Visual sampling of marked birds in Barcelona, Spain, and Pavia, Italy, showed that during any single census more than 70% of the population is not visible (Senar and Sol 1991; Barbieri 1993). Therefore, correction factors can increase the accuracy of a census. In a preliminary study using capture–recapture methods (Razzetti et al. 2002), we calculated the correction factor for the city of Milan to reduce biases due to the difficulty of locating all the birds that form one flock. According to other estimates for Mediterranean urban habitats, the numbers obtained during any census taken in Milan should be multiplied by a factor of 3.25 (for details see Razzetti et al. 2002).

Census counts in the urban area

Between 18 January and 3 February 2000 we counted feral pigeons by means of linear transects. We searched for birds in all 195 squares in Milan and along 214 km of roads comprising all the main avenues and more than 50% of the secondary roads. We also carried out an accurate census in all 11 parks and in the two main cemeteries. Censuses were performed by four counters simultaneously, each one in a different sector of the city. Birds were counted on the ground, after they flew down for food (corn) provided by the counters. To standardize counts, pigeons were attracted with the same amount of grain (nearly 250 g) at each observation point, and only birds that landed were considered. Transects were performed from late morning to afternoon, when feral pigeons exhibit peak feeding activity (Murton et al. 1972*a*, 1972*b*). All counts were multiplied by the factor of 3.25.

Census counts in farmland

Simultaneously with the census in the urban area, we counted feral pigeons at all 27 farmsteads inside the study area. Some pigeon flocks go on daily foraging flights from the urban area to farmsteads and then roost for a long period on roofs. Birds mainly feed on stored grain and food set out for cattle, but also directly in fields. Flights from the city occur early in the morning and flights back to the city in the late afternoon (R. Sacchi, A. Gentilli, E. Razzetti, and F. Barbieri, personal observation). Only a few birds stay at the farmsteads during the night and only a small fraction nest. Using binoculars we counted feral pigeons roosting on roofs or feeding in fields around farmsteads during the middle hours of the day, when most of the birds had reached the flock. Moreover, we conducted linear transects among farmsteads to census feral pigeons in fields. Since, in farmland, pigeons were not attracted by food given by the counters, we used binoculars to count all birds within 500 m on each side of a linear transect. Detectability of birds was high because of the low number of hedgerows and other natural barriers.

Building features and subdivision of the study area

We obtained urban maps of Milan that reported the distribution of buildings in 1885, 1924, 1936, 1950, 1965, 1972, and 1998 (Vercelloni 1987; Municipality of Milan 1990; Regione Lombardia 1998). By comparing the maps using GIS (MapInfo Pro, 1996), we prepared a map showing the present distribution of the dates of construction of buildings. We considered 1936 the borderline between old and new buildings. We split the city into 26 zones (Fig. 1) defined by the overlap of five concentric circular areas (centre of the city (A and B), suburb (C and D), and farmland (E); Fig. 1) and nine sectors based on the Administrative Districts of Milan (D.1 to D.9; Fig. 1). For each zone we measured the percentage of urban area and the percentage of buildings constructed before 1936.

Results

We found 247 flocks accounting for 55 650 birds in the urban area. Pigeons regularly frequented 94.7% (234 of 247) of the squares and all urban parks in the city. The number of birds forming the flocks was variable, ranging from 5–10 to several thousands. The average was 248 (SE = 46, range = 3–8000).

When not feeding or searching for food, pigeons usually rested in the same roost sites; generally these were roofs, entablatures, and eaves of buildings, wires, and, less frequently, trees along the streets. General features of roost sites were good exposure to the sun early in the morning, some protection from the elements, and a direct view of preferred feeding points. Nearly all large flocks in the urban area sustained themselves on food regularly given by people; we observed some people bringing up to 3–4 kg of grain daily, and to have a picture taken of oneself feeding pigeons in the main square (Piazza Duomo, with more than 8000 pigeons) is a tourist attraction. Other important local food sources were grain stores, markets, and shop sweepings, and also tree fruits (nettle tree (*Celtis australis*), elms (*Ulmus* spp.)), and seeds of herbaceous plants.

The 59.3% of farmsteads (16 of 27) that received flocks coming daily from the city together accounted for 48 000 pigeons. Therefore, the whole population of feral pigeons living in Milan was estimated at 103 650 birds; 53.7% of

Fig. 1. Subdivision of the city of Milan into 26 sectors in nine Administrative Districts (D.1 to D.9) and five concentric circular areas: city centre (A and B); suburbs (C and D); farmland (E).

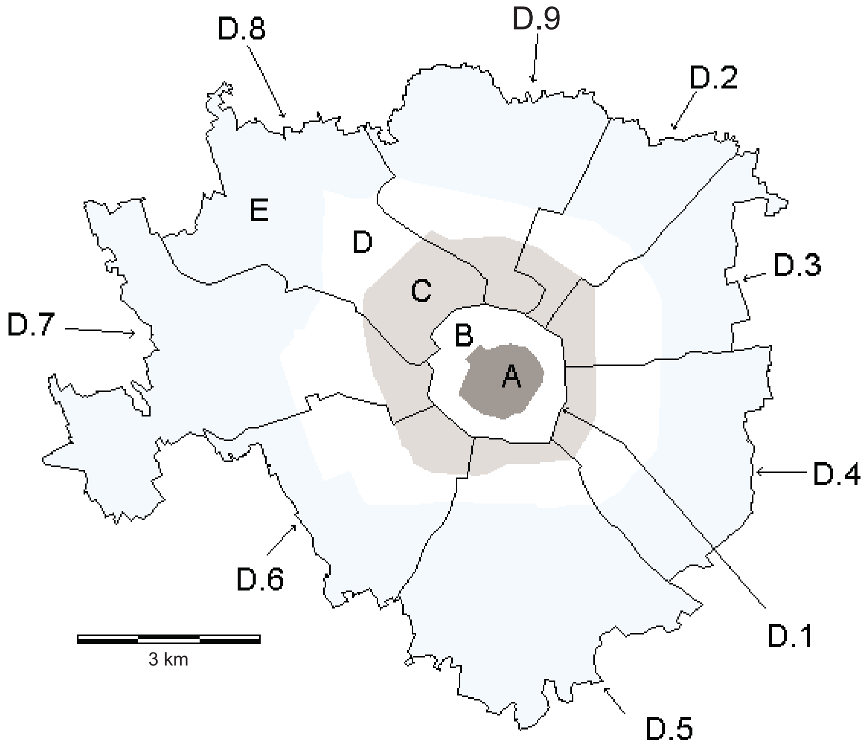


Table 1. Density of feral pigeons, *Columba livia* var. *domestica*, in five concentric circular sectors (A–E) in Milan.

Sector	Area (km^2)	No. of birds	Density (no./km^2)
Centre			
A	2.9	14 839	5117
B	6.6	4 948	750
A + B	9.5	19 787	2083
Suburb			
C	19.1	17 344	908
D	34.1	14 796	434
C + D	53.2	32 140	604
Farmland			
E	118.3	51 397	434
E*	118.3	3 390	29

Table 2. Density of feral pigeons in Administrative Districts of Milan.

District	Area (km^2)	No. of birds	Density (no./km^2)	Density* (no./km^2)
D.1	9.5	19 787	2083	2083
D.2	12.2	4 429	363	363
D.3	14.2	20 229	1425	675
D.4	21.2	11 363	536	185
D.5	29.7	16 514	556	118
D.6	18.4	11 901	647	83
D.7	30.8	10 931	355	142
D.8	24.7	2 739	111	111
D.9	20.7	5 431	262	262

*Excluding farmstead flocks.

the birds fed in the urban area, while 46.3% regularly made feeding flights to the farmsteads. There were 51 urban flocks with more than 250 birds, with 6 having >1000 birds.

Population density and distribution

The average population density in Milan was 570 pigeons/km^2 for the entire study area and 429/km^2 for the urban area only (farmstead birds were not considered). Nevertheless, feral pigeons were not regularly distributed in the city. Since both the number of pigeons and the number of flocks varied among the 26 zones, we subdivided the city (pigeons: $\chi^2_{[24]} = 463.11$, $p < 0.0001$; flocks: $\chi^2_{[24]} = 277.98$, $p < 0.0001$). The centre (D.1) and northeastern sector of the city comprising zones C and D of district D.3, and zone C of D.9, D.2, and D.4, had higher numbers of both pigeons and flocks than expected, while in the other zones, pigeon and flock numbers were lower or equivalent to those expected. The centre of the city (D.1) showed the greatest density, with 2083 birds/km^2 (5117 birds/km^2 in the inner part of the centre, zone A), while farmland showed the lowest density, with 434 birds/km^2 (Table 1). In D.4, D.5, D.6, and D.7, densities were high because of the pigeons found on farmsteads (Table 2). However, the population density decreased rapidly with increasing distance from the centre towards the suburbs and from the suburbs towards the farmland (Table 1). The regression model best fit relationship between the number of birds in each zone and the distance from the centre of the city was the third-degree polynomial regression

Fig. 2. Variation in numbers of feral pigeons, *Columba livia* var. *domestica*, in the five circular areas into which the city was divided (see Fig. 1).

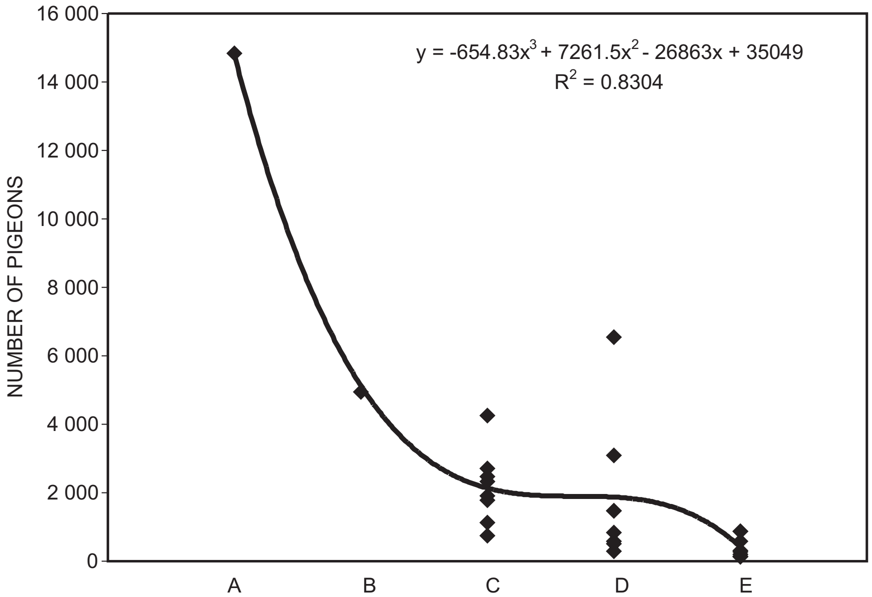
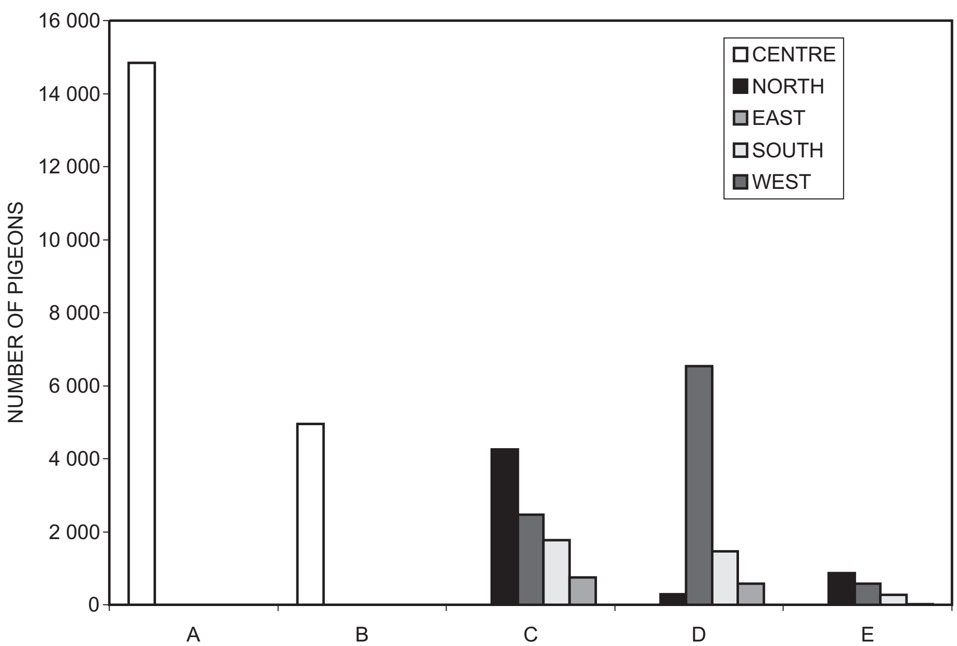


Fig. 3. Variation in numbers of pigeons in four different directions from the city centre.



($F_{[23]}$ = 35.89, N = 26, p < 0.001, R^2 = 0.83; Fig. 2). Linear and exponential models were also significant, but achieved lower F and R^2 values than the polynomial model. This was because population density did not decrease similarly in all directions, but increased, showing a second peak to the east (Fig. 3).

Effects of building features on pigeon distribution

Since 1885 the urban area of Milan has had two different periods of faster development: between 1900 and 1936 and between 1950 and 1965. Nevertheless, urban growth around the nineteenth-century core of the city was not uniform. At the beginning of the 20th century, the city grew mainly east and north, incorporating preexisting villages, whereas only after World War II did it develop west and south. Therefore, old buildings are primarily concentrated in the centre of the city (D.1) and in the inner parts (zones C and D) of D.2, D.3, and D.4 (Fig. 4).

Among 51 flocks accounting for more than 250 birds each, 47 (92.2%) were in squares with buildings constructed prior to 1936 ($\chi^2_{[2]}$ = 38.7, p < 0.0001); D.1 and D.3 contained 34 (66.7%) of these flocks ($\chi^2_{[2]}$ = 5.67, p = 0.017), while the 6 flocks with more than 1000 pigeons were in D.1 and the inner part (zone C) of D.9, D.2, and D.3 (Fig. 4).

Fig. 4. Distribution of 51 flocks accounting for more than 250 pigeons each (□, flocks with more than 1000 birds; shaded areas represent buildings constructed before 1936; ■, buildings constructed after 1936.

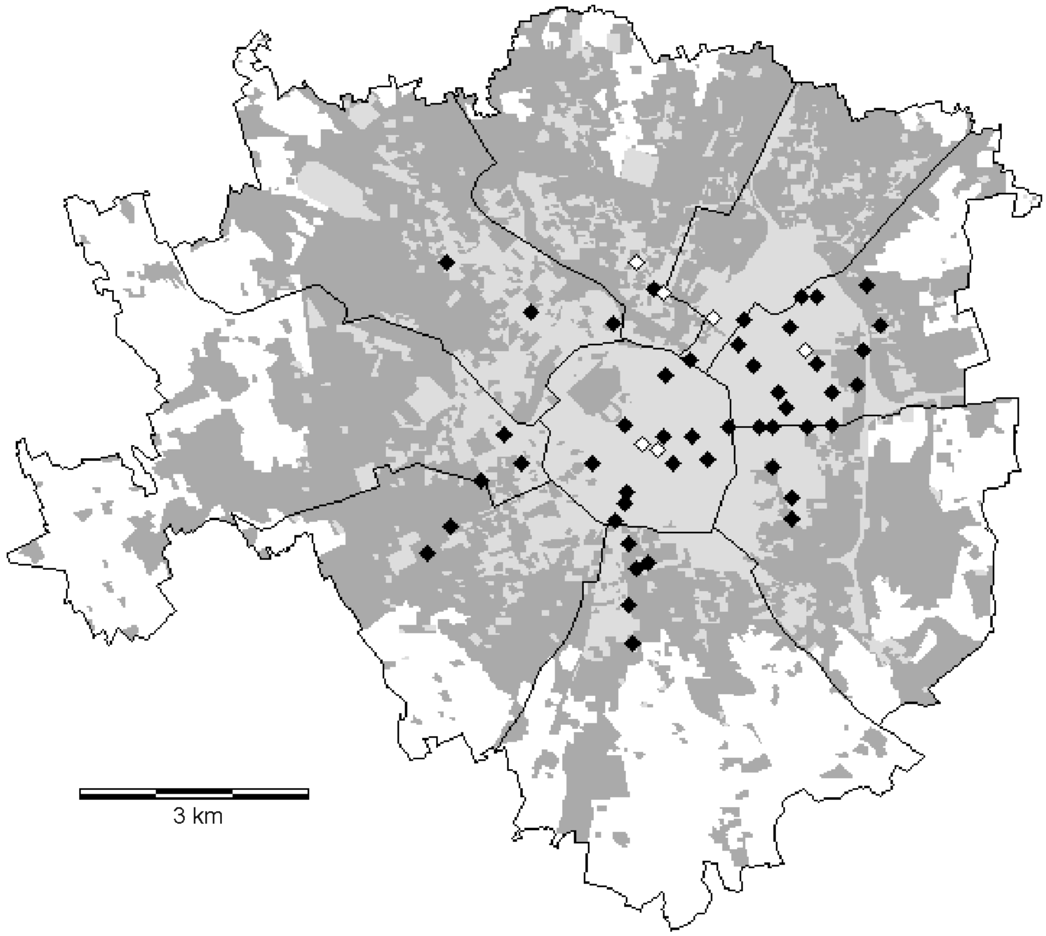
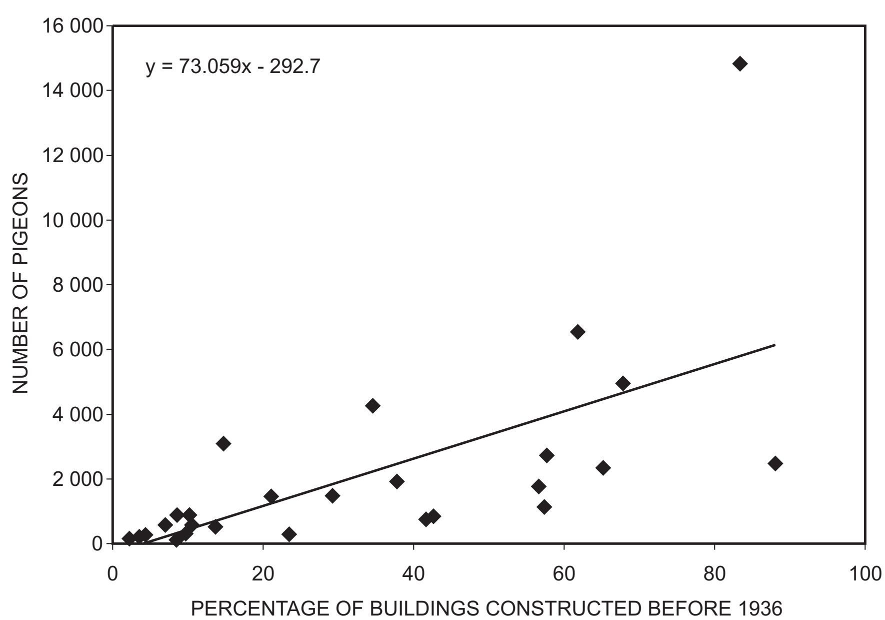
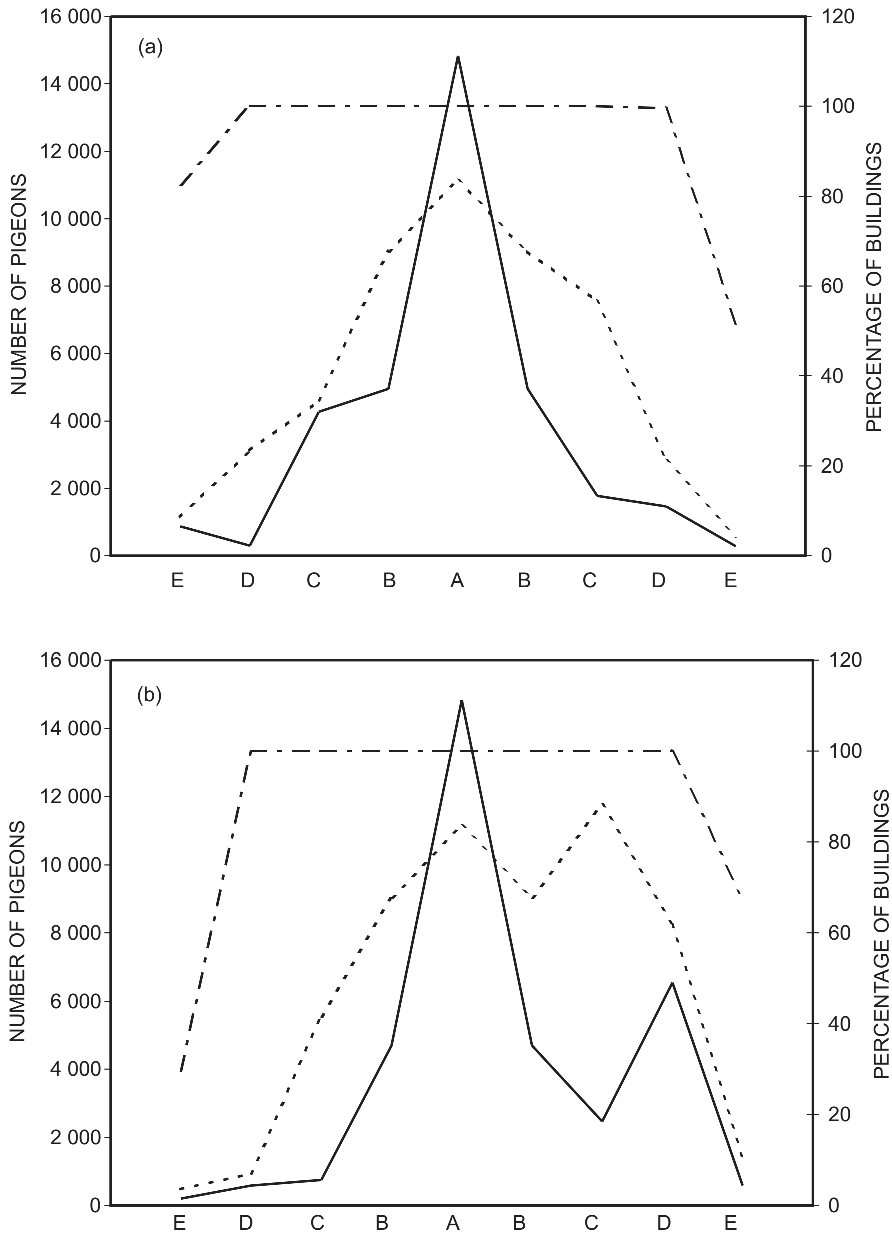


Fig. 5. Relationship between the number of pigeons and the percentage of buildings constructed before 1936.



The percentage of buildings constructed before 1936 in each of the 26 zones (Fig. 1) was positively related to the total number of birds ($y = 73.06x - 292.7$, $R^2 = 0.404$, $F_{[1,24]} = 16.28$, $p = 0.0005$; Fig. 5) and the total number of flocks ($y = 0.228x + 2.45$, $R^2 = 0.314$, $F_{[1,24]} = 10.54$, $p = 0.0036$) in the zone. Nonetheless, there was no significant relation-

Fig. 6. Variation in pigeon numbers (solid line) along two transects across the five concentric circular areas in the centre of the city: north–south (*a*) and west–east (*b*). The dotted line shows the percentage of buildings constructed before 1936 and the broken line shows the total percentage of urban area.



ship between the percentage of urban area and either the number of pigeons ($F_{[1,24]} = 3.11$, $p = 0.09$) or the number of flocks ($F_{[1,24]} = 3.61$, $p = 0.07$) in each zone.

The increased bird density we observed to the east was related to the increased percentage of buildings constructed before 1936 in the same direction. We found a strong correspondence between the number of birds and the percentage of old buildings along two transects across the city, north–south and west–east (Fig. 6).

Discussion

Although it is well established that feral pigeon populations increased close to the centre of the city (Johnston and Janiga 1985; Barbieri and De Andreis 1991; Jokimaki and Suhonen 1998), the extent and causes of this variation are poorly known. Greater food-resource accessibility and higher availability of roosting–breeding sites are the main factors usually invoked to explain this relationship (Johnston and Janiga 1985; Barbieri and De Andreis 1991). Here we show that features of buildings are related to the distribution and density of pigeons inside a wide and heterogeneous urban area. Although pigeons occurred all over the city of Milan and frequented 94.7% of the squares, the number of birds and number of flocks varied significantly according to age of buildings: the highest densities and largest flocks were found in the part of Milan constructed before 1936 (the centre and northeastern part of the town). Moreover, we found no relationship between the urban areas per se and bird densities, and the presence of a second peak of density in the eastern part of the city agreed only with the abundance of old buildings. Therefore, the pattern of population density and flock distribution observed in Milan could be explained by active selection of old buildings by pigeons.

In Milan, the 1930s marked the start of changes in the materials used by the building industry, which continued massively after World War II: bricks and roof tiles were gradually replaced by glass and reinforced concrete. This later kind of building is less suitable for feral pigeons because of the reduced availability of holes and openings for nesting.

Human population densities in Milan were similar in all Administrative Districts (excluding the centre) and decreased from the centre to the suburbs uniformly in all directions (Municipality of Milan 1998). The link between pigeon distribution and human population density, which is correlated with food availability (Jokimaki and Suhonen 1998), only partially explains the observed asymmetries of pigeon populations in Milan, and is not in accordance with the low values recorded in the inner parts of the southwestern districts or with the bimodal trend of pigeon numbers to the east.

Our results are of interest and have important implications for the management of feral pigeon populations because they suggest a link between feral pigeon abundance and an easily detectable feature of a town, like the age of buildings. Our approach may allow public authorities to identify areas preferentially used by pigeons on the basis of the date marking the shift from traditional to modern building materials. For Milan a good indicator of this shift was 1936. For other towns the date will differ depending upon their particular building history.

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