Feral Pigeons: Problems, Dynamics and Control Methods

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1. Introduction

Feral pigeons are birds now largely present with naturalized populations all around the world (Lever, 1987). The Rock Dove (*Columba livia*), which is their ultimate ancestor, was originally present in coastal and inland cliffs of central and western Palearctic and in the northern Ethiopian regions, as well as in those of the Indian subcontinent (Goodwin, 1983). These wild populations gave rise to domestic breeds as a result of artificial selection, having been the pigeons one of the first birds subjected to domestication (Sossinka, 1982). Domestics readily go feral, they have done so widely and in different times and locations', both in their natural range and in all continents where they were transported as captive birds, and subsequently introduced (Johnston & Janiga, 1995; Lever, 1987). Pigeons are granivorous birds tightly linked to arid and rocky habitats, so that feral populations remain linked to human settlements both as a consequence of their domestic origin and by these biological characteristics, that act in synergy (Baldaccini, 1996a). According to Goodwin (1978) the synanthropism of ferals is mainly a consequence of the food resources becoming available with the development of agriculture or otherwise mainly depends on the presence of buildings that constitute a vicariant habitat with respect to the natural one, as suggested by Hoffmann (1982). Food resources and human buildings are the key ecological factors that bring ferals into most cities and towns worldwide (Haag-Wackernagel, 1995), extensively in agricultural habitats and wherever man has constructed suitable recoveries to dwell in, forming stable or increasing populations of millions of individuals as stated by BirdLife International (2004) for Europe or Sauer et al. (2008) for the USA. The way by which feral pigeons established in urban habitats has been illustrated from a historical point of view by Ghigi (1950) and van der Linden (1950) and recently reviewed by Johnston & Janiga (1995), Haag-Wackernagel (1998) and Baldaccini & Giunchi (2006). Even in the Old World, synanthropic wild Rock Doves have a very marginal contribution to the constitution of feral populations (Ballarini et al., 1989; Johnston & Janiga, 1995).

2. Problem overview

The presence of feral pigeons in urban habitat and their degree of interactions with human life and activities can be perceived in many ways, ranging from harmless and

tame birds to harmful pests, depending on the personal cultural background (Jerolmack, 2008; Johnston & Janiga, 1995). Nevertheless, feral pigeons have a formidable capacity to become pest by any standard. Factors that have been identified as important in becoming a pest include the main characteristics of pigeons, such as being a granivore, having an alimentary storage crop, high reproductive rate, colonial habits and group foraging (Johnston & Janiga, 1995).

2.1 Public health risks

Feral pigeons are of considerable epidemiological importance, being reservoirs and potential vectors of a large number of microorganisms and source of antigens of zoonotic concern, causing both infections and allergic diseases, that can be lethal (Haag-Wackernagel, 2006; Haag-Wackernagel & Bircher, 2009; Haag-Wackernagel & Moch, 2004; Magnino et al., 2009; Rosický, 1978). Pathogens can be transmitted to humans mainly via excreta, secretions, or dust from feathers spread into the environment, thus a direct contact with pigeons can be unimportant (Curtis et al., 2002; Geigenfeind & Haag-Wackernagel, 2010). Pigeons breeding and roosting sites host an endless number of arthropods that may infest humans as bugs, fleas, mites and ticks. The latter are of particular human concern, as the soft tick *Argas reflexus* (Haag-Wackernagel & Bircher, 2009; Mumcuoglu et al., 2005). Lists of the different pathogenic organisms and of the most common parasitic arthropods identified in feral pigeons are reported by Johnston & Janiga (1995), Haag-Wackernagel & Moch (2004) and Haag-Wackernagel (2006). *Chlamydophila psittaci* is one of the most common pathogenic bacteria affecting at least European population of ferals (Magnino et al., 2009 and references therein); infection by different serotypes of *Salmonella* is on the contrary low (e.g. Pedersen et al., 2006). Regarding disease-producing fungi, Gallo et al. (1989) reported a percentage of pigeons infected by yeasts ranging from 7% (rural habitat) up to 22% (urban centre). According to these data, the most common pathogens transmitted to humans are *Chlamydophila psittaci* and the yeast *Cryptococcus neoformans*, while infections caused by *Salmonella* are very rare (Haag-Wackernagel & Moch, 2004), thus confirming a relationship between host population density and pathogenic transmission rate (Grenfell & Bolker, 1998). According to Haag-Wackernagel & Moch (2004), the risk of transmission of pathogens from pigeons to healthy humans is low, even for people in close contact with pigeons or their nests. On the contrary, immuno-depressed patients have a greater risk of infection in comparison to healthy people (Haag-Wackernagel & Moch, 2004). Feral pigeons, both in urban areas and in countryside, came in contact with different, often closely related, animal species thus enlarging their potential role as vectors of pathogens and parasites (Bevan 1990; Pedersen et al., 2006; Rosický, 1978). Pigeons have apparently introduced many avian pathogens into wild populations wherever they have been naturalized, infecting taxa as seabirds, penguins, raptors, other columbids and passerines (Phillips et al., 2003 and references therein).

Feral pigeons can also be the source of accidents of various nature, from the trivial slipping on surfaces littered by pigeon droppings, to the most serious problem of hazards to aircraft (bird-strike). As open habitats, in many cases not far from cities, airports attract selectively flocks of pigeons that are listed as one of the species more commonly involved in bird-strike events (Cleary et al., 2006; Dolbeer et al., 2000).

2.2 Infrastructural damages

Urban architectural problems constitute another factor of the negative relationship of humans and pigeons. Litter that accumulates under and on the surfaces used to roost or to nest are not only problematic from hygienic and urban deface reasons, they also cause structural and aesthetic damages to man-made structures accelerating their deterioration and increasing the costs of maintenance (Haag-Wackernagel, 1995; Pimentel et al., 2000). Damages are of particular relevance in the case of historic cities and towns, where buildings constitute ideal sites for nesting and roosting, contributing in a direct way to the growth of feral pigeon populations (Ballarini et al., 1989). Medieval buildings, for instance, whose external walls are plentiful of holes due to the building methods, constitute an ideal place for nesting (Ragni et al., 1996). Fowling of churches, architectural treasures and sculptures constitutes a serious problem for their conservation (Ballarini et al., 1989; Mendez-Tovar et al., 1995). Marbles and other calcareous stones are particularly damaged by the acidity of pigeon droppings that soil their surface. Indeed Bassi & Chiatante (1976) demonstrated that droppings from pigeons constitute a highly favourable substrate for fungal growth, that contributes to damaging the marble's surface both mechanically and by the excretion of acidic metabolies.

Pigeons do not only soil buildings but also foul foodstuffs; problems are relevant in particular places as grain elevators or food industries, all sites where scaring pigeons is of paramount importance for hygienic purposes related to food preparation (Gingrich & Osterberg, 2003).

2.3 Pigeons and agriculture

Agricultural landscape represents for pigeons an important and well exploited source of food that can influence in a direct way the population size of a given city. According to Hetmanski et al. (2010), the number of pigeons is significantly higher in towns located in agricultural landscape than in those surrounded by forests, at least in Poland. Countryside can host colonies in a variety of locations such as bridges, ruins or otherwise it can be visited by pigeons for feeding purposes with fast commuting foraging flights. This is a character that ferals largely share with Mediterranean Rock Doves (Baldaccini et al., 2000), whose occurrence may differ from town to town depending on a number of variables influencing pigeons' habits and needs; in fact in some cases foraging flights can be extremely rare (e.g. Sol & Senar, 1995). The distribution of food resources and the annual trend of reproductive attempts appear to exert a leading role in shaping the characteristics of these flights, as previously suggested both for feral pigeons (Soldatini et al., 2006) and for wild rock doves (Baldaccini et al., 2000 and references therein). The distances covered in such commuting flights vary between 3 and 20 km (see Rose et al., 2006 for a review), mainly depending on the landscape and distribution of food resources (Hetmanski et al., 2010; Soldatini et al., 2006). These foraging flights can be a significant source of damage for agriculture which adds to the damages done by colonies resident in the countryside. Pigeons can take seeds at the moment of sowing, destroy the just sprouted cotyledon leaves or feed widely on mature crops (Johnston & Janiga 1995).

The size of damage can vary according to main cultivations present in the area. For instance, in countries were wheat and maize are intensely cultivated, most of the damage occurs

during crops storage (Saini & Toor, 1991) because pigeons cannot feed actively on spikes. In other cases, such as sunflower fields, the damage can be greater, occurring both at sowing time and before harvesting, as pigeons are able to eat seeds directly from the flowers (van Niekerk & van Ginkel, 2004). Very little is known about the details of habitat selection by feral pigeons during their feeding flights towards croplands. Data collected during the springs 2010-2011 in the Pisa Province (central Italy), showed a preference for harvested fields of *Brassica* sp. and sowed fields of legumes (soybean *Glicine max* and chickpea *Cicer arietinum*) and sunflowers (*Heliantus annuus*) while other kinds of crops showed a strong negative selection (Fig. 1).
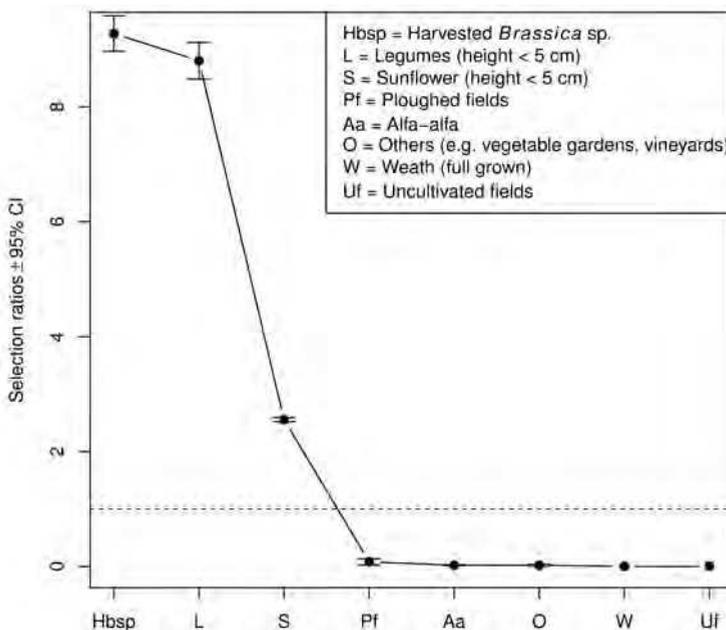

Fig. 1. Selection ratios (± 95% CI) according to design I (Manly et al., 2002) calculated on feeding feral pigeons (*n* = 12846 observations) in the agricultural landscape study area of Pisa Province (central Italy). The horizontal line indicates the threshold = 1 for positive selection.

2.4 Costs

While problems posed by pigeons have been largely assessed, only a few studies have quantified the direct costs and economic losses related to the species both in urban or countryside habitats (Bevan, 1990; Haag-Wackernagel, 1995; Phillips et al., 2003; Pimentel et al., 2000; Zucconi et al., 2003). From an economic point of view, all the different negative interactions causing damages or risks and all the actions to counteract or to evaluate the presence of ferals represent a cost. An example of the various sources of costs is presented in Fig. 2; as it can be noticed, some costs are independent on the number of pigeons present in a given site, while others are not.

Fig. 2. Chart of the source of costs due to feral pigeons' presence (from Zucconi et al. 2003, modified).

Published papers sometimes report total estimates for large areas: for instance Pimentel et al. (2000) estimated in 1.1 billion dollars per year the cost of pigeons in the USA, only for direct damages. In other cases, data are only incidental, giving examples of the costs relative to single cases or cities. The only available paper specifically focused on an analysis of the costs directly linked to pigeon presence is that by Zucconi et al. (2003), where the economic estimates were based on damage costs by private individuals and Municipalities in some sample cities from Italy. According to this paper, if we consider the costs of cleaning streets and squares, the percentage attributable to the presence of pigeons is in the range of 2.5-3.5% of the total cleaning costs in a single city. The cost was therefore estimated at 7-9 euros/pigeon/year. But if we consider the cleaning costs of historical buildings and artworks then the percentage increases to 10-15% of the total cleaning costs, with an individual cost ranging between 16 and 23 euros/pigeon/year, even though it should be noted that the costs related to damage to artworks are very difficult to estimate. According to Zucconi et al. (2003) it is impossible to make a reliable estimate of the sanitary and birdstrike costs in Italy. Costs of 2669 million dollars have been estimated in damages to civil aviation aircrafts in a period of seven years for the USA (Dolbeer et al., 2000).

In farmlands, the loss due to pigeon presence in Italy was estimated between 20-43 million euros/year, considering an estimated of crop loss of about 0.5-1% of the total yield (Zucconi et al., 2003). A more recent assessment suggested that the loss of sunflower seeds for South Africa caused by four species of *Columbiformes* amounts to 8.4% (van Niekerk, 2009). In a pilot study we conducted in farmlands surrounding the city of Pisa (ca. 200 ha), the daily average feral pigeons' density found in various types of crops was 5.7 ind/ha for sunflower and 19.1 ind/ha for legumes fields (soybean). Assuming each pigeon feeds only on farmland and has a food daily requirement of around 70 g of seeds (Johnston & Janiga, 1995), these values will be equivalent to a maximum damage of 400 and 1337 g of seeds/day respectively for sunflowers and soybean fields. If we consider that the number of individuals/ha reached peak values of 38 pigeons/ha, it is easy to understand how damages may be high; in these cases farmers are often forced to seed the fields again.

Given the amount of damage and the costs linked to pigeon presence it is often necessary to carry out several actions to reduce the number of pigeons present in the cities and, as a consequence, also the number of pigeons foraging in farmland. Actually, according to Haag-Wackernagel (1995), the damages caused by feral pigeons are reduced proportionally to the reduction of their number. An important component of the active costs related to pigeon control is the use of deterring systems on buildings, that can be easily estimated based on known prices of the components of the system. The costs of proofing with deterring systems was estimated by Zucconi et al. (2003) in 30,000-40,000 euros for 1 km² in an Italian city centre. In many European cities pharmacological sterilization methods are used to control pigeon population. For this method, costs range from 18-19 euros/pigeon/year for 800 ppm (Ovistop™, Acme Drugs, Italy) or 5000 ppm nicarbazin (OvoContol P™, Innolytics LLC, USA) up to 30 euros/pigeon/year for progesterone based products.

3. Population dynamics

Any properly designed control protocol involving lowering the number of an avian pest needs a thorough understanding of the population processes of the considered species (Feare, 1991). Estimates of the demographic parameters and of their variability are indeed crucial when selecting the control strategy as they provide sensible hints regarding the feasibility of attaining the objective of the control itself. Moreover, the same data collected during the control period could give useful information for adjusting the programme to the new characteristics of the population, especially when the likelihood of compensatory mechanisms (e.g. density-dependent variations in mortality or immigration rate) is not negligible, as for feral pigeons. The aim of this section is not to provide a thorough review of the available data on the demography of feral pigeons; instead, we discuss some data which are important in light of population control. The first thing to consider is that pigeons belonging to the same city constitute a single management unit. This is true for foraging behaviour, as suggested by the data collected from downtown area of Montreal which indicate that pigeons behave as a single population of consumers (Morand-Ferron et al., 2009), but it is particularly evident on the demographic point of view. Indeed, while breeding dispersal is almost absent (Hetmanski, 2007; Johnston & Janiga, 1995), juvenile dispersal within a given city is significant and, as estimated by data collected in Poland, approximately 30% of fledglings disperse each year on average (Hetmanski, 2007). As expected, the degree of dispersal is higher for high-density colonies (Fig. 3a) and most juveniles tend to move toward colonies with low density of breeding pairs. This implies that any local population reduction within a city would likely be compensated by the natural pattern of dispersal of young birds. On the other hand, the available data suggest that the rate of exchange among cities is almost absent (Hetmanski, 2007; Johnston and Janiga 1995).

As most bird pests, feral pigeons are *r*-selected organisms (Newton, 1998). Indeed, pigeon life-span is relatively short and rarely exceeds three years (Haag, 1990; Johnston & Janiga, 1995). This value is rather low considering the bird's size, as, according to the allometric equation reported in Atanasov (2008), the maximum life span of pigeon should be about 15 year. Mortality rates are thus high and this implies a high turnover rate. On the other hand, feral pigeons have a high breeding potential. They become sexually mature when six months old (Johnston & Janiga, 1995), although one-year-old birds usually represent a small fraction of the breeding segment of the population (Hetmanski, 2004; Johnston & Janiga,

1995). Moreover, while clutch size is small (only two eggs), the breeding season is long and could be regarded as lasting almost all year, with a spring-summer peak (Giunchi et al., 2007a; Hetmanski, 2004; Johnston & Janiga, 1995). Interestingly, the contribution of winter breeding attempts to the yearly number of fledglings is rarely negligible (Hetmanski, 2004; Johnston & Janiga, 1995) and in some cases absolutely relevant (e.g. 41% in Lucca, Italy; Giunchi et al., 2007a). This means that any action aimed at reducing the population size of feral pigeons, not only should be targeted to the whole or at least a significant part of the city, but also, especially if aimed at controlling the breeding output, should be continuous throughout the year. Other important things to consider are that replacement clutches are common and also the time needed for completing a single clutch is relatively short. Both parents share incubation and chick development is quite fast, given the use of the energy-rich cropmilk (Shetty et al., 1992). Moreover, pigeons can overlap clutches (Hetmanski & Wolk, 2005; Johnston & Janiga, 1995), which enables the clutch interval to be shortened, thereby increasing the number of clutches within a season. All these features indicate that feral pigeons are characterized by a high intrinsic demographic rate of increase (Neal, 2004).
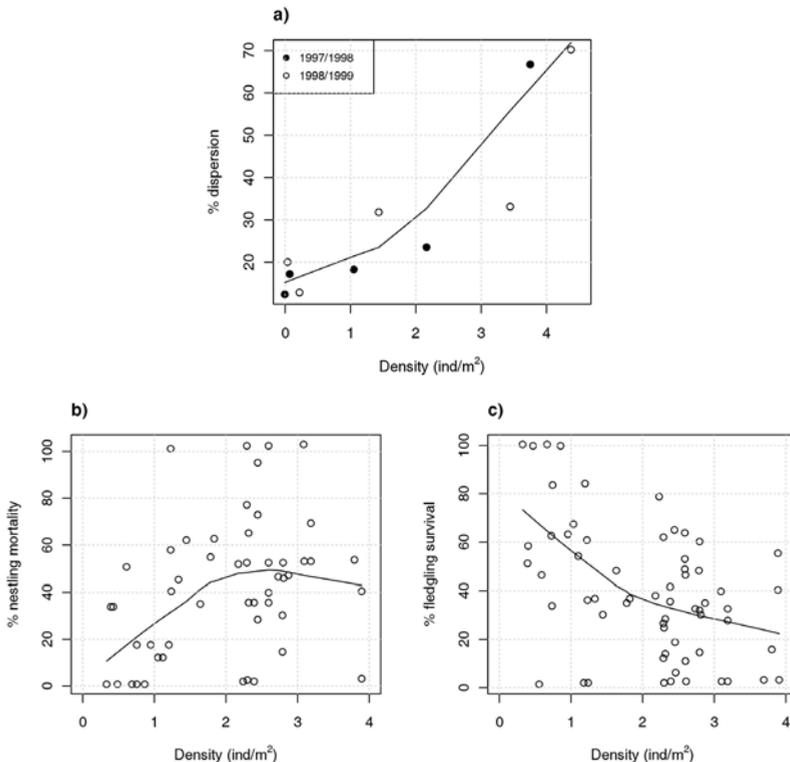

Fig. 3. Examples of density-dependence of three demographic parameters in feral pigeons (smoothing calculated by means of LOWESS; span=0,70). a) Percentage dispersion of juveniles (from Hetmanski 2007a, modified). b-c) Percentage of nestling mortality and fledging survival as a function of population density (from Haag 1988, modified).

A third important common feature of pigeon populations is the density-dependence of demographic parameters. Indeed, reproductive success, inter-clutch interval, adult mortality, immigration and recruitment rate show various degrees of density-dependence (references in Hetmanski, 2007; Hetmanski & Barkowska, 2007; Hetmanski & Wolk, 2005; Johnston & Janiga, 1995), being high at low density and low at higher density of birds (see Fig. 3). This means that populations of feral pigeons have a high compensatory potential, which is particularly evident when considering the rapid recovery of populations subjected to considerable harvesting during pest control activities (Johnston & Janiga, 1995; Kautz & Malecki, 1991; Senar et al., 2009; Sol & Senar, 1992).

All the above mentioned characteristics, associated to the mild climate and the high levels of food availability and productivity typical of most temperate and boreal urban ecosystems (Müller & Werner, 2010), leads to hypothesize that most populations of feral pigeons have reached the limit of the carrying capacity of the urban environment, after the substantial increase occurred during the second half of the last century (1940-1970), following changes in agricultural practices and the human demographic explosion after World War II (Johnston & Janiga, 1995). This implies that, excluding recent colonized cities or newly built outskirts of cities (e.g. Haag, 1988; Senar et al., 2009), most of the historical (and largest) populations of feral pigeons should be almost stable, provided that the environmental conditions which affect population abundance (e.g. human population density, prevalent structural characteristics of buildings, habitat features of the surrounding landscape; Buijs & Van Wijnen, 2001; Hetmanski et al., 2010; Johnston & Janiga, 1995; Jokimäki & Suhonen, 1998; Sacchi et al., 2002) did not change significantly. This pattern is clearly confirmed for Hamburg, where four censuses conducted during the second half of the last century indicates that feral pigeon population increased markedly from 1953 to 1966 and remained at a high level thereafter (Rutz, 2008; Fig. 4a). Moreover, periodic censuses performed during the last decades of the 20th century in a small number of cities (e.g. Barcelona, Bratislava) revealed a noticeable intra-annual, but a very low inter-annual variability of counts of resident pigeons (Johnston & Janiga, 1995). This low inter-annual variability is confirmed for two Italian cities, characterized by very different environmental conditions: Venice and Pisa. Venice (urban area: ca. 7 km², inhabitants: ca. 70,000) is located in Northern Italy and it is an island in a large wetland, while Pisa (urban area: ca. 10.3 km², inhabitants: ca. 90,000) is located in central Italy and it is surrounded by large agricultural areas where pigeons could find plenty of food. Given these conditions, the number of pigeons in Venice foraging in the mainland is rather small (e.g. < 900 pigeons/day recorded in October 2004; Baldaccini et al., unpubl. data) and birds rely on food resources within the city, favoured by the extremely high tourist presence during spring-summer months (Soldatini et al., 2006). On the other hand, the number of commuting pigeons we observed in Pisa is quite high (e.g. > 6500 pigeons/day recorded from two observation points in October 1995; Baldaccini et al. unpubl. data) and pigeons make extensive use of farmland for feeding. In spite of these differences, data indicate that in absence of significant control measures, both populations did not show any positive trend in recent years (Fig. 4b, c). Obviously, these two case studies do not represent the whole variability of abundance of pigeons, but clearly show that at least in those cities which have a sufficiently long history of presence of feral pigeons, the local populations do no show any significant inter-annual trend, at least over short-mid periods.
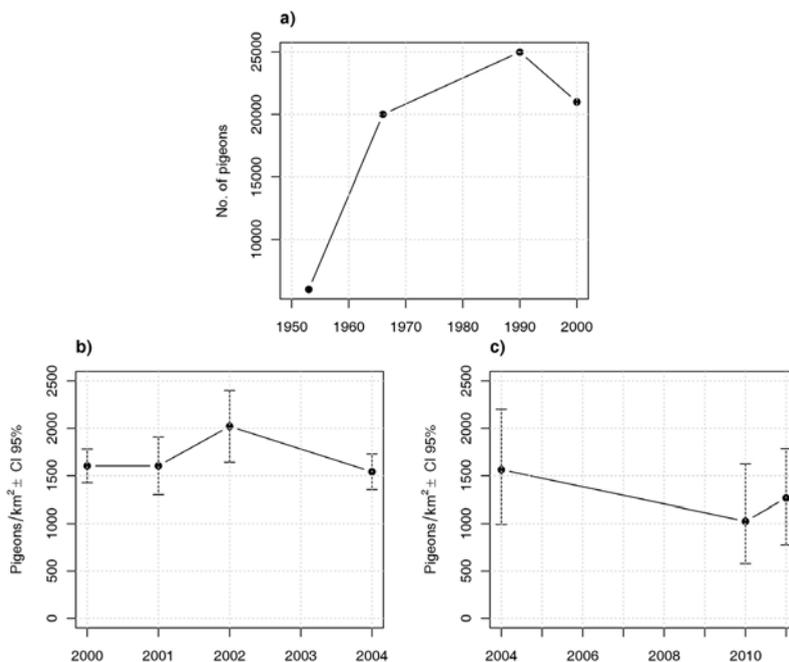
Fig. 4. a) Number of pigeons counted in the city of Hamburg in the period 1953-2000 (from Rutz 2008, modified). b) Venice: density of feral pigeons estimated by means of late-autumn uncorrected quadrat counts in the period 2000-2004 (from Giunchi et al. 2007b, modified). c) Pisa: density of feral pigeons estimated in February by means of distance sampling in the period 2004-2011 (Vanni et al., unpublished data).

4. Monitoring and control methods

4.1 Monitoring

The definition of pest should incorporate the requirement that the species actually cause economic damage (Hone, 1994) and it is the damage that justifies any control programme. However, most control programmes regarding feral pigeons lack of appropriate damage estimations, simply relying on pigeon numbers as a surrogate of the impact of the species. This approach clearly shows how monitoring and control are intimately related. More generally, estimates of pest abundance are essential not only for the assessment of pest population size to justify control, but also for the choice of appropriate control methods, with a plausible estimate of their costs and effectiveness. Unfortunately, while the development of pest control techniques for feral pigeons have involved a significant amount of research (see below), in comparison, research aimed to develop unbiased methods for estimating pigeon population size has aroused far less interest. Pigeons counts are intrinsically difficult both because of the characteristics of urban environments (complex structure and poor visibility) and of the pigeons themselves (clustered distribution and high density; Buijs & Van Wijnen, 2001; Giunchi et al., 2007b; Johnston & Janiga, 1995; Jokimäki & Suhonen, 1998). Probably for these difficulties, several authors adopted *ad hoc* and uncalibrated indexes of population abundance, such as: (1) counts of naturally occurring

flocks (e.g., Buijs & Van Wijnen, 2001; Haag-Wackernagel, 1995); (2) counts of birds attracted with food (Dobeic et al., 2011; Sacchi et al., 2002); (3) counts carried out by walking along a random sample of square, non-overlapping sampling units ('quadrat counts'; Senar, 1996; Sol & Senar, 1992). While still widely used in wildlife management due to their relatively low costs, population indexes are however highly criticized because their critical assumption (proportionality between index and true population density) is usually violated in real situation (see Sutherland, 1996; Williams et al., 2002 and references therein). In the case of feral pigeons, this often led to the impossibility of an objective evaluation and quantification of the actual effects of most pest control programmes (see Giunchi et al., 2007b for further details). More reliable population estimates have been obtained by combining the quadrat counts with the use of 'correction factors', which take into account the imperfect bird detectability and are estimated by using a mark-resight procedure on a subsample of the study area (Sacchi et al., 2002; Senar, 1996). In fact, this method can produce accurate results, but it is costly as it requires catching a significant number of birds, and entails that the correction factor is estimated for each condition, as the number of birds that will pass undetected in different surveys is variable, depending on the characteristics of the study area and on the density and behaviour of pigeons themselves (Giunchi et al., 2007b). Recently, Giunchi et al. (2007b) proposed the use of distance sampling as a valuable alternative for estimating pigeons abundances. The method consists in counting pigeons on line-transects randomly distributed over the urban area and then adapted to the urban road network. During censuses the position of detected birds is accurately determined and then used for estimating detection probability according to the procedures of distance sampling (Buckland et al., 2001). The main problem of the method is that, contrary to the recommendations of Buckland et al. (2001), as transects followed the urban road network, (1) they do not represent a random sample of various habitats of the city, and (2) they are located on roadways where pigeon density is low, since birds are usually disturbed by road traffic. These conditions, intrinsically related to the structure of urban habitats, could lead to a significant underestimate of population density which can be reduced by left-truncating the data in order to exclude the low-density area near each transect. In spite of the possible biases due to the not rigorously random distribution of transects and to the spiked nature of collected distances, distance sampling in urban environment turned out to be highly repeatable, as suggested by the estimates collected in two consecutive year (2010 and 2011) in Pisa, with the same methodologies (see Fig. 4c), even though the high variability of the estimates has to be acknowledged. Provided that censuses were performed when pigeons are not at their annual population peak (i.e. late summer-autumn), the methods turned out to be consistent in different cities, with different architectural characteristics, as exemplified by Pisa, Bolzano and especially Venice, where the urban road network is not used by motor vehicle and thus roads and squares constitute available habitat for pigeons, which, on the contrary, could find a lot of food there (e.g. wastes, or food provided by the citizen or tourists) (Fig. 5). Moreover, it should be noted that the above-mentioned theoretical problems mostly affect the accuracy of distance sampling, but not its repeatability, given their dependence on the structural characteristics of the urban environment, which should be roughly the same in different years. This means that even a systematically biased distance sampling should be an unbiased tool for detecting population trends. On the contrary, the repeatability of other *ad hoc* methods (e.g. quadrat counts) probably depend also on the density of pigeons, as commonly observed for several indexes of abundance (Sutherland, 1996). This means that any control programme aimed at significantly reducing pigeon population size has to

calibrate the adopted index of abundance, in order to estimate correctly the population trend and thus to evaluate the effect of the control. Given the above consideration, distance sampling should be regarded as a rather promising approach for monitoring feral pigeons, also considering its relatively low operative costs (Giunchi et al., 2007b). Actually, it should be noted that in recent years distance sampling has been increasingly used for estimating bird population size in urban habitat (Fuller et al., 2009) and that the method has been included in the guidelines for managing feral pigeons by some Italian local administrations (e.g. Piedmont Regional Authority, www.regione.piemonte.it/sanita/sanpub/animale /dwd/colombi.pdf). We believe that techniques aimed at giving reasonable estimates of pigeon populations size, such as distance sampling, have to be considered as a critical component of any effective management programme, because they help to assess both the costs for control and its effectiveness, by objectively quantifying their effects on pigeons abundance.
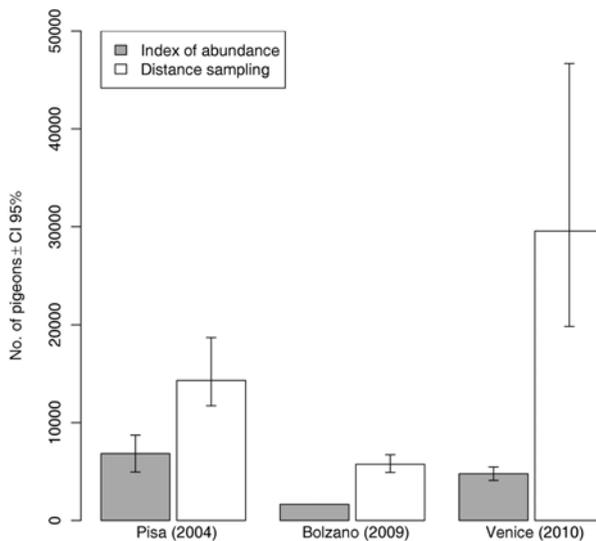

Fig. 5. Comparison of late-winter counting results between distance sampling and indexes of abundance in three Italian cities. **Pisa.** Index of abundance = quadrat counts carried out on 6.25-ha sample units (n = 40) proportionally allocated to two strata ; distance sampling carried out on 40 line transect proportionally allocated to the same two strata (more details in Giunchi et al., 2007b). **Bolzano.** Index of abundance = counts of feeding flocks at 11 traditional feeding sites used by public authorities to control pigeon food, to facilitate captures for epidemiological investigation and for distributing chemosterilants (Baldaccini & Mongini, 1991; Carsaniga, 1996); distance sampling carried out on 40 transects proportionally allocated to three strata. **Venice.** Index of abundance = quadrat counts carried out on 6-ha sample units (n = 36); distance sampling = data collected on 36 line transects put in the very centre of each quadrat and crossing almost all the length of the unit itself. All distance sampling analyses closely followed the approach detailed in Giunchi et al. (2007b), except for Venice, where data were not left-truncated. It is important to note that, given its peculiar urban structure, with a high densities of narrow streets, detection probability is particularly reduced in Venice.

4.2 Control

Given the above-mentioned peculiar interactions between humans and feral pigeons, it is important that control actions should be calibrated on the approach that the inhabitants of a given city have towards the pigeons, so that the control actions are accepted and will have an increased chance of success (Conover, 2002). Methods used to control pigeon populations could be essentially clustered in three main categories: 1) culling; 2) decrease of reproductive success; 3) reduction of habitat carrying capacity.

4.2.1 Culling

Several models indicate that for monogamous species with high mortality rates and high productivity, such as feral pigeons, culling is likely less effective than the reduction of reproductive potential for controlling population (Barlow et al., 1997; Dolbeer, 1998). Actually, even though culling has been widely applied to feral pigeon populations in several cities in the past (see e.g. Feare, 1991; Johnston & Janiga, 1995; Murton et al., 1972; Sol & Senar, 1992) and it is still used in several contexts (see e.g. Senar et al., 2009), no scientific study has demonstrated the efficacy of this approach in significantly affecting population size. As indicated above, the high intrinsic demographic rates of pigeons and the strong density dependence of several demographic parameters determine that pest control mortality is often compensatory (Feare, 1991; Johnston & Janiga, 1995) up to a relatively high threshold level estimated to be over 30% of the population/year by Kautz & Malecki (1991). Given the size of most pigeon populations, especially those producing significant damages, these figures could be high (thousands of individuals), which poses several technical problems. Moreover massive killing of pigeons is difficult to accept by many citizens, which determines further problems of ethical nature.

4.2.2 Decrease of reproductive success

Egg removal, egg puncturing or dummy eggs have been used in several cities, especially from public urban dovecotes set up with the aim to limit reproductive success (Baldaccini & Giunchi, 2006; Jacquin et al., 2010; Johnston & Janiga, 1995). This kind of method is almost inapplicable in 'natural' colonies, which are often difficult to reach, and it is costly in urban dovecotes, requiring cleaning and maintenance. Moreover this practice could affect egg laying cycles of birds, suggesting that feral pigeons respond to egg-removal by multiplying reproduction attempts (Jacquin et al., 2010). Furthermore egg quality is negatively affected by egg removal, suggesting that such management procedures can lead to an increase of reproductive physiological costs and to a decrease of female condition, raising issues about its potential consequences on parasite resistance and health status of urban populations (Jacquin et al., 2010). In any case, we are not aware of any quantitative estimation of the efficacy of this kind of approach for pest control.

The use of chemosterilants (e.g. cytostatic agents, synthetic progestinic and estrogenic drugs or drugs that interfere with the birds' metabolic activities) has received much more attention (see Ballarini et al., 1989; Giunchi et al., 2007a and references therein). Some results in terms of reduction of the population size and improvement in the health status of the birds have been reported (e.g. Baldaccini, 1996b; Dobeic et al., 2011), even though there are no

evidences of significant long-term effects. The recent development of new reproductive inhibitors based on nicarbazin (e.g. Ovistop™, OvoContol P™) provided new interest for this kind of approach (Avery et al., 2008; Giunchi et al., 2007a; Yoder et al., 2006). While some authors report significant but sometimes puzzling effects of drug distribution on usually small populations (e.g. Bursi et al., 2001), no well controlled data on the long-term effects of these chemosterilants are available. More generally, as the effects are only partial (a maximum of 59% reduction of productivity under controlled conditions; Avery et al., 2008) and temporary (Yoder et al., 2005), drugs such as nicarbazin are likely to produce only short lasting reductions of pigeon abundance in the field, with a rapid recovery as soon as the treatment is stopped (Giunchi et al., 2007a).

4.2.3 Reduction of carrying capacity

Carrying capacity reduction through habitat modification is at present the most reliable way to obtain long-lasting effects on pigeon populations (Haag, 1993); moreover this method is usually well accepted (and sometimes requested) by citizens. Carrying capacity reduction should act on two main factors: nest/roost sites and food.

The limitation of nest and roost sites may be achieved by applying exclusions or scare techniques (Johnston & Janiga, 1995). Different kinds of tactile or mechanical repellents had been used to deter pigeons (Haag-Wackernagel, 2000; Seamans et al., 2007; Williams & Corrigan, 1994). Chemical, acoustic, and visual repellents are known to be effective only for short time periods as pigeons habituate to them within a few days (Johnston & Janiga, 1995), while no deterring effect was observed when using an ultrasonic or repellent odour system (Haag-Wackernagel, 2000). On the other hand, mechanical devices, such as porcupine wires, can be surmounted if bird motivation to access a given site is high enough (Haag-Wackernagel, 2000). Buildings and structures can be also designed to reduce the attractiveness to pigeons (Haag-Wackernagel & Geigenfeind, 2008; Williams & Corrigan, 1994). While applied in midtown areas, train stations, airports and historical buildings, exclusion methods are rarely integrated into a systematic pest control program, as wrongly thought to be ineffective (Magnino et al., 2009). However, they proved to be highly effective in Perugia (Italy) resulting in a reduction of 23% of the population of feral pigeons in one year (Ragni et al., 1996).

As suggested by Haag (1991, 1993), control of food supply is the basis for a successful control programme, also determining a general improvement of the population quality and resistance to parasites and pathogens. Food resources management may be particularly effective when feral pigeon populations mostly depend on food resources located within the urban environment (see Murton et al., 1972; Rose et al., 2006; Sol & Senar, 1995). In this case it can be possible to manage food availability, although both theoretical considerations and field data indicates that this may be difficult (see Giunchi et al. 2007a and references therein). Besides published data (see e.g. Haag 1993), as a successful example we may report the case of Venice, where, until a few years ago it was allowed the distribution of corn for feeding the pigeons as a touristic attraction. It was estimated that pigeons were fed 350 tons of corn per year and the number of pigeons present in St Mark's Square was critically high, reaching concentrations of >10,000 individuals in 1.3 ha. In May 2008, the local Authorities decided to ban the distribution of corn and since then the number of pigeons has decreased dramatically, down to a maximum of 1000 individuals at one time in St Mark' Square.

Quadrat count estimations of birds density, obtained in late autumn (November, $n = 9$ years) and in late winter (February-March, $n = 7$ years) from 1996 confirmed the decreasing trend in both census periods (Pearson correlations, late autumn: $r = -0.81$, $P = 0.008$; late winter: $r = -0.86$; $P = 0.013$). But more in detail, considering densities recorded in the city before and after 2008 we can assess that differences are significant both in late autumn (ANOVA: $F_{1,8} = 6.82$, $P = 0.035$) and in late winter ($F_{1,6} = 8.89$, $P = 0.031$). Substantial differences were recorded also in foraging flights. Indeed the number of commuting birds recorded before (2004) and after (2009) the ban occurred had dramatically decreased all over the year (t-test: departing flock sizes $t_{11} = 7.44$, $P \ll 0.001$; returning flock sizes $t_{11} = 5.36$, $P \ll 0.001$; number of departing flocks in 2004 N=818 *vs.* N=213 in 2009 and of retuning flocks in 2004 N= 590 *vs.* N= 170 in 2009). Thus, the reduction of food resources within the city had not been compensated for by any increase in foraging flights towards the countryside. This is probably due to the fact that Venice is an island in a wetland that pigeons must fly over to reach mainland foraging sites and experimental data by Wagner (1972) reported the avoidance by pigeons in crossing a body of water. On the contrary, the management of food resources should be less effective in cities where most birds fly for food to adjacent agricultural areas (see e.g. Soldatini et al., 2006). In this last case, bird scaring devices and reflecting strips as well as gas cannons are extensively used by farmers, but with a very low long term effectiveness. The use of culling of limited numbers of individuals as scaring method linked together with scarecrows and gas cannons is applied in some Italian provinces but the results of these methodologies are still under considerations (Baldaccini et al., unpublished data).

4.3 A population model

All the above considered control methods have their own drawbacks, depending on the characteristics of feral pigeon populations (e.g. size), on the features of the urban habitat (e.g. age of buildings), and on the characteristics of the surrounding landscape (e.g. distribution of food resources). This means that the different techniques could be more effective/easy to apply in different context and suggest the usefulness of a combination of methods in order to reach better results in shorter time. To evaluate the possible effects of the use of some combination of control methods on feral pigeon populations, we simulated a number of scenarios by means of the software VORTEX 9.50 (Miller & Lacy, 2005). The aim of these simulations was not to provide a precise demographic forecast of a given population subjected to pest control, instead to give some hints regarding the choice of a proper pest control programme.

4.3.1 Methods

The values used as initial input for simulations are reported in Table 1. On the whole, the approach we followed was roughly the same adopted in Giunchi et al. (2007a) and we do not report all the details here. The main differences, with respect to the above-mentioned paper were:

1. In order to extend the considered scenarios, we modelled two populations, which we called 'Murton' and 'Haag', as demographic parameters were partly derived from papers published by Murton et al. (1972, 1974) and by Haag (1988, 1990). The 'Murton' population was characterized by a comparable mortality rate between adults and

juveniles (values derived from Murton et al., 1972), while the 'Haag' population had a rather high juvenile mortality and low adult mortality (values obtained as the average of those reported in Haag, 1988).

2. Density dependence was modelled not by varying the percentage of breeding females in the population, instead the number of fledglings (NF) per female. This latter parameter is indeed more frequently reported than the former one, which is only a matter of speculation in a few papers (Johnston & Janiga, 1995). The equation we used was of the same type of that adopted for the percentage of breeding females in Giunchi et al. (2007a):

$$NF(N) = NF(0) - \left[\left(NF(0) - NF(K) \right) \left(NK \right)^{B} \right] \tag{1}$$

where NF(N), NF(K) and NF(0) are the number of fledglings per females that breed when the population size is N, at carrying capacity (K), and at extremely low density (near 0), respectively, while the exponent B is a constant which determines the form of the curve. To simplify calculations, we considered only the case of B = 2. This appears a reasonable assumption, given that, as suggested by Fowler (1981), density dependence in reproductive success can often be modelled with a quadratic function (see also Fig. 3). NF(K) was chosen by trial and error as the values which determined a fundamental stability of the population defined by the other demographic parameters listed in Table 1 in the absence of density-dependent reproduction and with a carrying capacity much higher than the initial population size (10,000 birds). Interestingly, at least for the 'Haag' population, this value was quite comparable to that reported for a numerically stable colony in the city centre of Basel (Haag, 1988). Given this comparability, NF(0) for the Haag population was set to the value reported in Haag (1988) for a recently settled colony in the periphery of Basel, where density of pigeons was rather low. We then assumed that the 'Murton' population behaves in the same way, and thus we hypothesized the same proportional increase.

3. We considered two types of scenarios. In one scenario both populations were near carrying capacity (K = 5,000), while in the other K was set to 10,000. In this way we modelled two different situations: old populations, with relatively stable numbers, and relatively recent populations with increasing size.

4. To simplify calculations, we did not consider any environmental variability, also because no data in this regard could be found in the literature.

A series of simple simulations was performed to investigate the effects of different degrees of reduction of fertility with a reduction of K. We considered three scenarios for the reduction of fertility (-15%, -30% and -60% of the fertility of the whole population) with a maximum set to the maximum effect obtained with the recently proposed chemosterilants based on nicarbazin (see Avery et al., 2008) and four scenarios for the reduction of K (no reduction, -1%/year, -2%/year, -4% year). We did not simulate an abrupt reduction of carrying capacity, because this is often difficult to obtain in the field.

All pest control programme lasted 10 years. We did not consider culling in our simulation because of the lack of evidence regarding its efficacy and its above-mentioned technical problems. In order to simplify calculations and in absence of detailed information useful for

modelling, mortality rate was considered density-independent, although some data regarding American populations indicated an increased survival of pigeons following an experimentally induced decrease of population density (Kautz & Malecki, 1991). In this regard, it is important to notice that Haag (1988, 1990) did not report any remarkable difference in mortality and in age distribution of pigeons in colonies characterized by significantly different densities. Obviously, it is important to emphasize that this choice had the consequence of increasing the theoretical effect of the simulated pest control, because it cut down the recovery potential of the modelled population when density was low (see also Newton 1998).

Variable	'Murton'	'Haag'
Number of simulations	100	100
Period	10 years	10 years
Initial population size (N)	5,000	5,000
Start at stable age distribution	Yes	Yes
Carrying capacity (K)	5,000, 10,000	5,000, 10,000
Demographic closure	Yes	Yes
Inbreeding	0 lethals	0 lethals
Catastrophes	0	0
Mortality at age 0	43	82
Mortality at age 1	34	10
Breeding system	Long term monogamy	Long term monogamy
Age of first breeding	1	1
Maximum Age of Reproduction	7	7
Sex ratio at birth	0.5	0.5
% females breeding	100	100
Density dependence	Yes	Yes
Number of fledglings when N=K	1.3	2.2
Number of fledglings when N=0	2.4	4.0
B	2	2
% males in the breeding pool	100	100

Table 1. Summary of the input parameters used in the simulations.

4.3.2 Results

When population size was very near to K, we observed a rather similar outcome for both 'Murton' and 'Haag' populations regarding the fertility control (Fig. 6). In both cases, when the fertility control was high (-60%) the impact of the reduction of K was not significant. Less strong reduction of fertility had rather less impact on the populations and a rather poor additive effect with respect to the decrease of K. When the population was increasing, the impact of the reduction of K was obviously lower than in the former cases, and it was only evident after a few years, when the populations began to level off (Fig. 7). For both populations, the final outcome of the simulations depended on the reduction of K only when the fertility control rates were low; otherwise the differences were slight or absent. It should be noted that only the strongest controls (last scenarios) inverted the positive trend of population size.
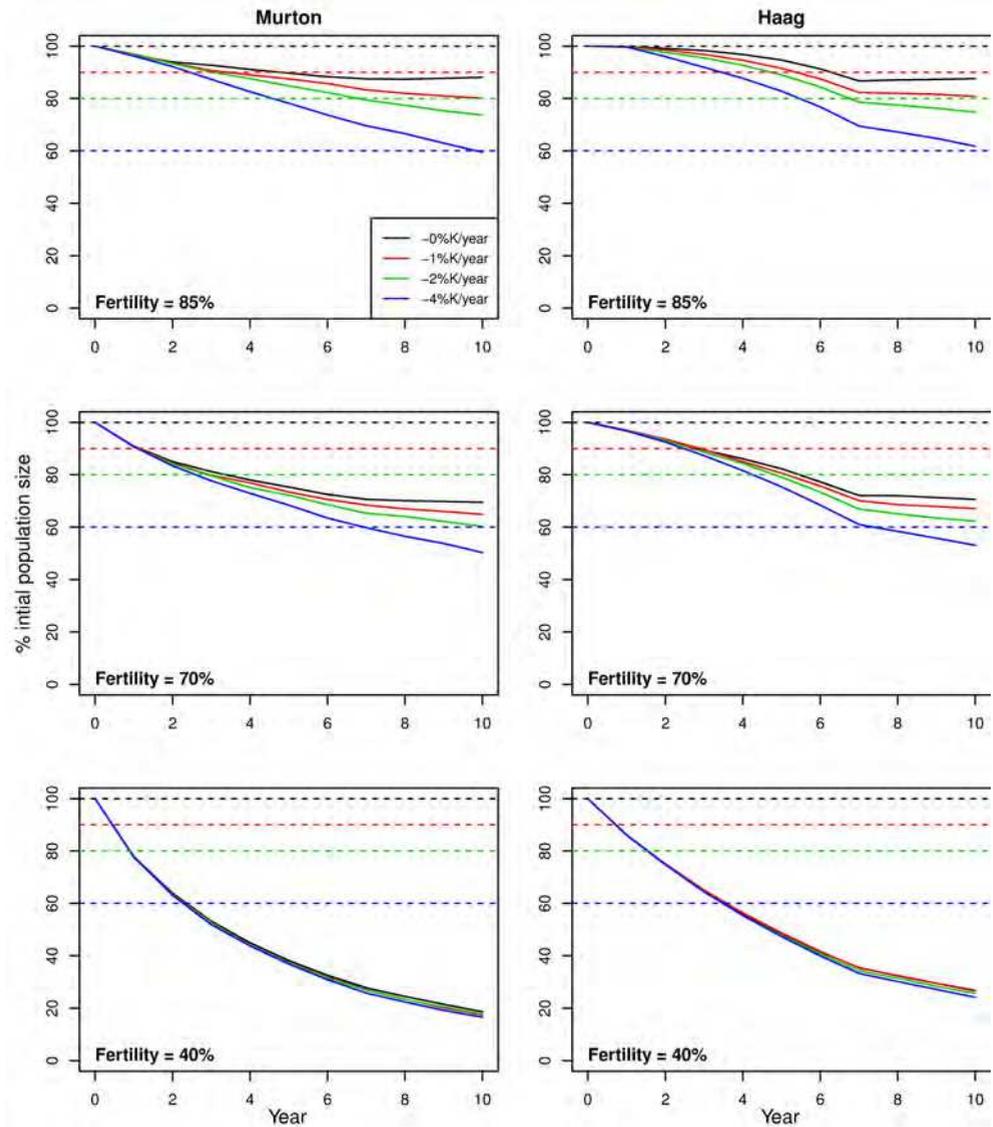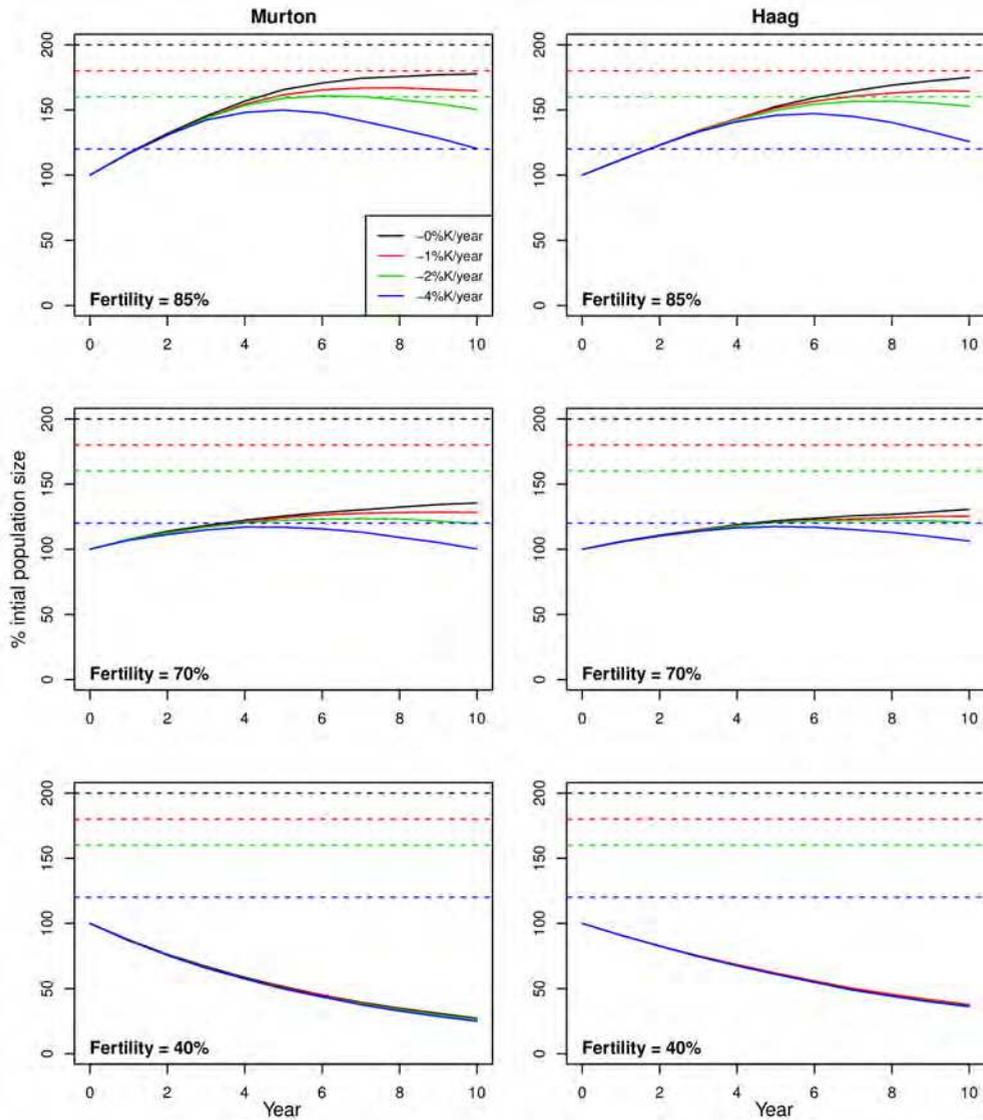
Fig. 6. Feral pigeons population size near the carrying capacity (K) of the urban habitat. Trends (continuous lines) of the 'Murton' and 'Haag' populations predicted after 10 years of various degrees of fertility control (-15, -30, -60%) combined with different degrees of reduction of carrying capacity. Broken lines refer to the cumulative population reduction which could be obtained by only reducing K [e.g. red line: -0.1%/year * 10 years = -10%)].

Fig. 7. Feral pigeons population size at 50% of the carrying capacity (K) of the urban habitat. Trends (continuous lines) of the 'Murton' and 'Haag' populations predicted after 10 years of various degrees of fertility control (-15, -30, -60%) combined with different degrees of reduction of carrying capacity. See Fig. 6 for other details.

5. Concluding remarks

The potential for compensation is one of the most important features which has to be taken into account when starting a pest control programme on feral pigeons. For this reason, an effective management policy should focus on the reduction of carrying capacity of the urban habitat, possibly integrating other approaches according to the characteristics of both the city and pigeon population. Carrying capacity reduction through habitat modification is indeed the most effective way for obtaining long-lasting effects on pigeon abundance. This could be obtained by focusing on all the ecological resources, and not only on foods, as, in some situations it is not easy to control all birds' feeding sites. Among the other above-considered control methods, culling is probably the less reliable, as in most cases it revealed to be not effective and often problematic both under the practical and ethical point of view, especially for large populations. Our simulations also indicate that, under certain circumstances, fertility control could be profitably combined with the reduction of carrying capacity. When it is difficult to distribute chemosterilants to the population (e.g. because the population is very large or food resources are abundant and widespread), the additive effects are only marginal. On the other hand, when the fertility control could be strong (e.g. small populations), the need for a reduction of carrying capacity is less stringent. It is however important to underline that: (1) as mentioned above, our simulations overestimated the effects of the fertility control; (2) the reduction of the carrying capacity is the only way for capitalizing the results obtained by any other method, whose effects are often fleeting and reversible. For this reason, this last method should be considered even in those cases where it is not the best for obtaining strong and rapid results (e.g. when it is not possible to have a strong impact on carrying capacity at least on the short term or when the population is far from the carrying capacity), also because several actions aimed at reducing the ecological resources for pigeons (e.g. exclusion from the most profitable nest/roost sites) could sum up over several years. In this context, budget availability is an important factor to consider in choosing the management policy, as fertility control may result expensive compared to e.g. food reduction especially if applied for long periods. Therefore, it is extremely important for the city council to carefully evaluate its capacity to afford the application of different control methods for several years.

In general terms an effective management policy needs a strong local background knowledge in order to be calibrated to the characteristics of the considered population. This implies a carefully balanced integration of control methods, proper monitoring and reliable modelling, in order to forecast the effects of control actions (Chee & Wintle, 2010). It is therefore important to understand the behavioural and ecological characteristics of the pigeon population before starting a control programme, and to analyse the capability of covering the costs and the participation and awareness of the municipal Authorities and city dwellers.

6. Acknowledgments

7. References

Atanasov, A. T. (2008). The near to linear allometric relationship between the total metabolic energy per life span and the body mass of aves. *Journal of Animal and Veterinary Advances,* Vol. 7, No. 4, pp. 425–432, ISSN 1993-601X

Avery, M. L.; Keacher, K. L. & Tillman, E. A. (2008). Nicarbazin bait reduces reproduction by pigeons (*Columba livia*). *Wildlife Research,* Vol. 35, No. 1, pp. 80–85, ISSN 1035-3712

Baldaccini, N. E. (1996a). Inurbamento: processo attivo alla ricerca di spazi da colonizzare. *Controllo delle popolazioni ornitiche sinantropiche: "problemi e prospettive",* ISS/WHO/FAO-CC/IZSTe/96.27, Roma, October 1993, pp. 2-13

Baldaccini, N. E. (1996b). La diminuzione della capacità riproduttiva come mezzo di controllo dei colombi urbani. *Controllo delle popolazioni ornitiche sinantropiche: "problemi e prospettive",* ISS/WHO/FAO-CC/IZSTe/96.27, Roma, October 1993, pp. 103-105

Baldaccini, N. E. & Giunchi, D. (2006). Le popolazioni urbane di colombo: considerazioni sulla loro genesi e sulle metodologie di gestione. *Biologia Ambientale,* Vol. 20, pp. 125-141

Baldaccini, N. E.; Giunchi, D.; Mongini, E. & Ragionieri, L. (2000). Foraging flights of wild rock doves (*Columba l. livia*): a spatio-temporal analysis. *Italian Journal of Zoology,* Vol. 67, No. 4, pp. 371–377, ISSN 1748-5851

Baldaccini, N. E. & Mongini, E. (1991). Diminuzione del numero di colombi di città a Bolzano in seguito a interventi di controllo. *Supplemento alle Ricerche di Biologia della Selvaggina* Vol. 17, pp. 215-217, ISSN 1121-3973

Ballarini, G.; Baldaccini, N. E. & Pezza, F. (1989). *Colombi in città. Aspetti biologici, sanitari e giuridici. Metodologie di controllo*. Istituto Nazionale di Biologia della Selvaggina, Bologna

Barlow, N. D.; Kean, J. M. & Briggs, C. J. (1997). Modelling the relative efficacy of culling and sterilisation for controlling populations. *Wildlife Research,* Vol. 24, No. 2, pp. 129-141, ISSN 1035-3712

Bassi, M. & Chiatante, D. (1976). The role of pigeon excrement in stone biodeterioration. *International Biodeterioration Bulletin*, Vol. 12, No. 3, pp. 73-79, ISSN 0020-6164

Bevan, R.D.R. (1990) The costs of feral pigeons. In *British Ornithological Union, Proceedings of a Symposium*, October 1990, ADAS/British Ornithologists' Union, London, pp. 10–11.

BirdLife International (2004). *Birds in Europe,* BirdLife International, ISBN 0946888531, Wageningen, The Netherlands.

Buckland, S. T.; Anderson, D. R.; Burnham, K. P.; Laake, J. L.; Borchers, D. L. & Thomas, L. (2001). *Introduction to Distance Sampling: Estimating Abundance of Biological Populations,* Oxford University Press, ISBN 0198509278, New York

Buijs, J. A. & Van Wijnen, J. H. (2001). Survey of feral rock doves (*Columba livia*) in Amsterdam, a bird-human association. *Urban Ecosystems*, Vol. 5, No. 4, pp. 235-241, ISSN 1573-1642

Bursi, E.; Gelati, A.; Ferraresi, M. & Zannetti, G. (2001). Impiego della nicarbazina nel controllo della riproduzione del colombo randagio di città. *Annali della Facoltà di Medicina Veterinaria di Parma,* Vol. 21 , pp. 97-115, ISSN 0393-4802

Carsaniga, G. (1996). Controllo dei colombi di città a Bolzano: analisi di un'esperienza pilota. *Controllo delle popolazioni ornitiche sinantropiche: "problemi e prospettive",* ISS/WHO/FAO-CC/IZSTe/96.27, Roma, October 1993, pp. 74-78.

Chee, Y. E.; Wintle B. A. (2010). Linking modelling, monitoring and management: An integrated approach to controlling overabundant wildlife. *Journal of Applied Ecology*, Vol. 47, No. 6, pp. 1169-1178, ISSN 0021-8901

Cleary, E. C., Dolbeer, R. A. & Wright, S. E. (2006). Wildlife strikes to civil aircraft in the United States 1990-2005, In: DigitalCommons@University of Nebraska – Lincoln, Available from http://digitalcommons.unl.edu/birdstrikeother/7/

Conover, M. R. (2002). *Resolving Human-Wildlife Conflicts: The Science of Wildlife Damage Management,* Lewis Publishers, ISBN 156670538X, Boca Raton, Fla

Curtis, L.; Lee, B. -S; Cai, D.; Morozova, I.; Fan, J. -L; Scheff, P.; Persky, V.; Einoder, C. & Diblee, S. (2002). Pigeon allergens in indoor environments: a preliminary study. *Allergy,* Vol. 57, No. 7, pp. 627-631, ISSN 0105-4538

Dobeic, M.; Pintarič, Š.; Vlahović, K. & Dovč, A. (2011). Feral pigeon (*Columba livia*) population management in Ljubljana. *Veterinarski arhiv., Vol.* 81, No. 2, pp. 285–298, ISSN 0372-5480

Dolbeer, R. A. (1998). Population dynamics: the foundation of wildlife damage management for the 21st century. In: DigitalCommons@University of Nebraska – Lincoln, Available from http://digitalcommons.unl.edu/vpc18/9/

Dolbeer, R. A.; Wright, S. E. & Cleary, E. C. (2000). Ranking the hazard level of wildlife species to aviation. *Wildlife Society Bulletin,* Vol. 28, No. 2, pp. 372-378, ISSN 0091-7648

Feare, C. J. (1991). Control of bird pest populations. In: *Bird population studies: relevance to conservation and management,* C.M. Perrins, J.D. Lebreton & G.J.M. Hirons (Eds), 463-478, Oxford University Press, ISBN 0198577303, Oxford, UK

Fowler, C. W. (1981). Density dependence as related to life history strategy. *Ecology,* Vol. 62, No. 3, pp. 602-610, ISSN 0012-9658

Fuller, R. A.; Tratalos, J., & Gaston, K. J. (2009). How many birds are there in a city of half a million people? *Diversity and Distributions*, Vol. 15, No., pp. 328–337, ISSN 1366-9516

Gallo, M. G.; Cabeli, P. & Vidotto, V. (1989). Sulla presenza di lieviti patogeni nelle feci di colombo torraiuolo (*Columba livia*, Gmelin 1789, forma urbana) della città di Torino. *Parassitologia* Vol. 31, No. 2-3, pp. 207-212, ISSN 0048-2951

Geigenfeind, I. & Haag-Wackernagel, D. (2010). Detection of *Chlamydophila psittaci* from feral pigeons in environmental samples: problems with currently available techniques. *Integrative Zoology* , Vol. 5, No. 1, pp. 63–69, ISSN 1749-4869

Ghigi, A. (1950). *Piccioni Domestici e Colombicoltura*, REDA, Roma

Gingrich, J.B.; Osterberg, T.E. (2003). Pest birds: Biology and Management at Food Processing Facilities. In: *Food plant sanitation,* Y.H. Hui, B.L. Bruinsma, J.R. Gorham, W.K. Nip, P.S. Tong & P. Ventresca (Eds), 317–339, Marcel Dekker, ISBN 0824707931, New York

Giunchi, D.; Baldaccini, N. E.; Sbragia, G. & Soldatini, C. (2007a). On the use of pharmacological sterilisation to control feral pigeon populations. *Wildlife Research,* Vol. 34, No. 4, pp. 306-318, ISSN 1035-3712

Giunchi, D.; Gaggini, V. & Baldaccini, N. E. (2007b). Distance sampling as an effective method for monitoring feral pigeon (*Columba livia* f. *domestica*) urban populations. *Urban Ecosystems*, Vol. 10, No. 4, pp. 397-412, ISSN 1573-1642

Goodwin, D. (1978). *Birds of man's world,* Cornell University Press, ISBN 080141167X, Ithaca, NY

Goodwin, D. (1983). *Pigeons and Doves of the World,* 3rd edition. Cornell University Press, ISBN 0801414342, New York

Grenfell, B. T. & Bolker, B. M. (1998). Cities and villages: infection hierarchies in a measles metapopulation. *Ecology Letters*, Vol. 1, No. 1, pp. 63–70, ISSN 1461-023X

Haag, D. (1988). Die dichteabhängige Regulation im Brutschwarm der. Strassentaube *Columba livia* forma *domestica*. *Der Ornithologische Beobachter* , Vol. 85, pp. 209-224.

Haag, D. (1990). Lebenserwartung und Altersstruktur der Strassentaube *Columba livia* forma *domestica*. *Der Ornithologische Beobachter,* Vol. 87, pp. 147-151

Haag, D. (1991). Population density as a regulator of mortality among eggs and nestlings of feral pigeons (*Columba livia domestica*) in Basel, Switzerland. In: *Nestling mortality of granivorous Birds due to Microorganisms and Toxic Substances,* J. Pinowski, B.P. Kavanagh & W Górski (Eds.), 21-31. Polish Scientific Publishers, ISBN 8301104767, Warsaw

Haag, D. (1993). Street Pigeons in Basel. *Nature,* Vol. 361, No. 6409, p. 200, ISSN 0028-0836

Haag-Wackernagel, D. (1995). Regulation of the street pigeon in Basel. *Wildlife Society Bulletin,* Vol. 23, No. 2, pp. 256-260, ISSN 0091-7648

Haag-Wackernagel, D. (1998). *Die Taube: Vom heiligen Vogel der Liebesgöttin zur Strassentaube,* Schwabe, ISBN 3796510167, Basel

Haag-Wackernagel, D. (2000). Behavioural responses of the feral pigeon (Columbidae) to deterring systems. *Folia Zoologica,* Vol. 49, No. 2, pp. 101-114, ISSN 0139-7893

Haag-Wackernagel, D. (2006). Human diseases casued by feral pigeons. In: *Advances in Vertebrate Pest Management Vol. 4,* C. Feare & D. P. Cowan (eds.), 31-58, Filander Verlag, ISBN 3930831643, Furth

Haag-Wackernagel, D. & Bircher, A. J. (2009). Ectoparasites from feral pigeons affecting humans. *Dermatology,* Vol. 220, No. 1, pp. 89-92, ISSN 1018-8665

Haag-Wackernagel, D. & Geigenfeind, I. (2008). Protecting buildings against feral pigeons. *European Journal of Wildlife Research, Vol.* 54, No. 4, pp. 715-721, ISSN 1439-0574

Haag-Wackernagel, D. & Moch, H. (2004). Health hazards posed by feral pigeons. *Journal of Infection,* Vol. 48, No. 4, pp. 307-313, ISSN 0163-4453

Hetmanski, T. (2004). Timing of breeding in the Feral Pigeon Columba livia f. domestica in Slupsk (NW Poland). *Acta Ornithologica,* Vol. 39, No. 2, pp. 105-110.

Hetmanski, T. (2007). Dispersion asymmetry within a feral pigeon *Columba livia* population. *Acta Ornithologica,* Vol. 42, No. 1, pp. 23-31

Hetmanski, T. & Barkowska, M. (2007). Density and age of breeding pairs influence feral pigeon, *Columba livia*, reproduction. *Folia Zoologica*, Vol. 56, No. 1, pp. 71–83.

Hetmanski, T.; Bochenski, M.; Tryjanowski, P. & Skórka, P. (2010). The effect of habitat and number of inhabitants on the population sizes of feral pigeons around towns in northern Poland. *European Journal of Wildlife Research,* Vol. 57, No. 3, pp. 421-428, ISSN 1439-0574

Hetmanski, T. & Wolk, E. (2005). The effect of environmental factors and nesting conditions on clutch overlap in the feral pigeon *Columba livia* f. *urbana* (Gm.). *Polish Journal of Ecology,* Vol. 53, No. 4, pp. 523-534, ISSN 1505-2249

Hoffmann, H. (1982). *Das Taubenbuch,* Krüger, ISBN 3810507113, Frankfurt

Hone, J. (1994). *Analysis of Vertebrate Pest Control*. Cambridge University Press, ISBN 0521415284, Cambridge.

Jacquin, L., Cazelles, B., Prevot-Julliard, A.-C., Leboucher, G. & Gasparini, J. (2010). Reproduction management affects breeding ecology and reproduction costs in feral urban Pigeons (*Columba livia*). *Canadian Journal of Zoology, Vol.* 88, No. 8, pp. 781-787, ISSN 0008-4301

Jerolmack, C. (2008). How pigeons became rats: The cultural-spatial logic of problem animals. *Social Problems*, Vol. 55, No. 2, pp. 72–94, ISBN 0037-7791

Johnston, R. F. & Janiga, M. (1995). *The Feral Pigeons,* Oxford University Press, ISBN 0195084098, London

Jokimäki, J. & Suhonen, J. (1998). Distribution and habitat selection on wintering birds in urban environments. *Landscape and Urban Planning*, Vol. 39, No. 4, pp. 253-263, IISSN 0169-2046

Kautz, J. E. & Malecki, R. A. (1991). *Effects of Harvest on Feral Rock Dove Survival, Nest Success and Population Size*. U.S. Dept. of the Interior, Fish and Wildlife Service, Washington, D.C

Lever, C. (1987). *Naturalized Birds of the World,* Wiley, ISBN 978-0582460553, New York.

van der Linden, C. G. (1950). *Le Pigeon Voyageur,* Payot, Paris

Magnino, S.; Haag-Wackernagel, D.; Geigenfeind, I.; Helmecke, S.; Dovc, A.; Prukner-Radovcic, E.; Residbegovic, E.; Ilieski, V.; Laroucau, K.; Donati, M.; Martinov, S. & Kaleta, E. F. (2009). Chlamydial infections in feral pigeons in Europe: Review of data and focus on public health implications. *Veterinary Microbiology,* Vol. 135, No. 1-2, pp. 54-67, ISSN 0378-1135

Manly, B. F.; McDonald, L.; Thomas, D. L.; McDonald, T. L. & Erickson, W. P. (2002). *Resource Selection by Animals: Statistical Design and Analysis for Field Studies,* 2nd edition, Kluwer Academic Publishers, ISBN 1402006772, Dordrecht, The Netherlands

Mendez-Tovar, L. J.; Mainou, L. M.; Pizarro, S. A.; Fortoul-Vandergoes, T. & Lopez-Martinez, R. (1995). Fungal biodeterioration of colonial facades in Mexico City. *Revista Mexicana de Micologia*, Vol. 11, pp. 133–144

Miller, P. S. & Lacy, R. C. (2005). *A Stochastic Simulation of the Extinction Process. Version 9.50 User's Manual.* Conservation Breeding Specialist Group (SSC/IUCN), Apple Valley, MN, Available from http://www.vortex9.org/vortex.html

Morand-Ferron, J.; Lalande, É. & Giraldeau, L. (2009). Large scale input matching by urban feral pigeons (*Columba livia*). *Ethology, Vol.* 115, No. 7, pp. 707-712, ISSN 0179-1613

Müller, N. & Werner, P. (2010). Urban biodiversity and the case for implementing the convention on biological diversity in towns and cities. In: *Urban Biodiversity and Design,* N. Müller, P. Werner, & J.G. Kelcey (Eds), 1–33, Wiley, ISBN 9781444332667, Chichester, UK

Mumcuoglu, K. Y.; Banet-Noach, C.; Malkinson, M.; Shalom, U. & Galun, R. (2005). Argasid ticks as possible vectors of West Nile virus in Israel. *Vector-Borne & Zoonotic Diseases,* Vol. 5, No. 1, pp. 65–71, ISSN 1530-3667

Murton, R. K.; Thearle, R. J. P. & Coombs, C. F. B. (1974). Ecological studies of the feral pigeon *Columba livia* var. III. reproduction and plumage polymorphism. *Journal of Applied Ecology*, Vol. 11, No. 3, pp. 841-854, ISSN 0021-8901

Murton, R. K.; Thearle, R. J. P. & Thompson, J. (1972). Ecological studies of the feral pigeon *Columba livia* var. I. Population, breeding biology and methods of control. *Journal of Applied Ecology*, Vol. 9, No. 3, pp. 835-874, ISSN 0021-8901

Neal, D. (2004). *Introduction to Population Biology*. Cambridge University Press, ISBN 0511078692, Cambridge

Newton, I. (1998). *Population Limitation in Birds*. Academic Press, ISBN 0125173652, San Diego

van Niekerk, J. H. (2009). Loss of sunflower seeds to columbids in South Africa: economic implications and control measures. *Ostrich, Vol.* 80, No. 1, pp. 47-52, ISSN 698572454

van Niekerk, J. H. & van Ginkel, C. M. (2004). The feeding behaviour of pigeons and doves on sown grain crops on the South African Highveld. *Ostrich,* Vol. 75, No. 1-2, pp. 39-43, ISSN 698572454

Pedersen, K.; Clark, L.; Andelt, W. F. & Salman, M. D. (2006). Prevalence of shiga toxin-producing *Escherichia coli* and *Salmonella enterica* in rock pigeons captured in Fort Collins, Colorado. Journal of Wildlife Diseases, Vol. 42, No. 1, pp. 46-55, ISSN 0090-3558

Phillips, R. B., Snell, H. L. & Vargas, H. (2003). Feral rock doves in the Galápagos Islands: Biological and economic threats. *Noticias de Galápagos,* Vol. 62, (December 2003), pp. 6-11

Pimentel, D.; Lach, L.; Zuniga, R. & Morrison, D. (2000). Environmental and economic costs of nonindigenous species in the United States. *BioScience,* Vol. 50, No. 1, pp. 53-65, ISSN 0006-3568

Ragni, B.; Velatta, F. & Montefameglio, M. (1996). Restrizione dell'habitat per il controllo della popolazione urbana di Columba livia. *Controllo delle popolazioni ornitiche sinantropiche: "problemi e prospettive",* ISS/WHO/FAO-CC/IZSTe/96.27, Roma, October 1993, pp. 106-110

Rose, E., Nagel, P. & Haag-Wackernagel, D. (2006). Spatio-temporal use of the urban habitat by feral pigeons (*Columba livia*). *Behavioral Ecology and Sociobiology*, Vol. 60, No. 2, pp. 1-13, ISSN 0340-5443.

Rosický, B. (1978). Healt risks associated with animals in different types of urban areas: Present status and new ecological conditions due to urbanization. *Annali dell'Istituto Superiore di Sanità*, Vol. 14, No. 2, pp. 273-286, ISSN 0021-2571

Rutz, C. (2008). The establishment of an urban bird population. *The Journal of Animal Ecology,* Vol. 77, No. 5, pp. 1008–1019, ISSN 1365-2656

Sacchi, R.; Gentilli, A.; Razzetti, E. & Barbieri, F. (2002). Effects of building features on density and flock distribution of feral pigeons *Columba livia* var. *domestica* in an urban environment. *Canadian Journal of Zoology,* Vol. 80, No. 1, pp. 48-54, ISSN 0008-4301

Saini, H. K. & Toor, H. S. (1991). Feeding ecology and damage potential of feral pigeons, Columba livia, in an agricoltural habitat. *Le Gerfaut*, Vol. 81, pp. 195-206, ISSN 0016-9757

Sauer, J. R.; Hines, J. E. & Fallon, J. (2008). The North American Breeding Bird Survey, Results and Analysis 1966-2007. Version 5.15. 2008. USGS Patuxent Wildlife Research Center, Laurel, MD.

Seamans, T. W.; Barras, S. C. & Bernhardt, G. E. (2007). Evaluation of two perch deterrents for starlings, blackbirds and pigeons. *International Journal of Pest Management,* Vol. 53, No. 1, pp. 45–51, ISSN 0967-0874

Senar, J. C. (1996). Bird census techniques for the urban habitat: a review. *Controllo delle popolazioni ornitiche sinantropiche: "problemi e prospettive"*, ISS/WHO/FAO-CC/IZSTe/96.27, Roma, October 1993, pp. 36-44

Senar, J. C.; Carrillo, J.; Arroyo, L.; Montalvo, T. & Peracho, V. (2009). Estima de la abundancia de palomas (*Columba livia* var.) de la ciudad de Barcelona y valoración de la efectividad del control por eliminación de individuos. *Arxius de Miscel·lània Zoològica, Vol.* 7, No. 1, pp. 62–71, ISSN 1698-0476

Shetty, S.; Bharathi, L.; Shenoy, K. B. & Hegde, S. N. (1992). Biochemical properties of pigeon milk and its effect on growth. *Journal of Comparative Physiology B.,* Vol. 162, No. 7, pp. 632-636, ISSN 0174-1578

Soldatini, C.; Mainardi, D.; Baldaccini, N. E. & Giunchi, D. (2006). A temporal analysis of the foraging flights of feral pigeons (*Columba livia* f. *domestica*) from three Italian cities. *Italalian Journal of Zoology,* Vol. 73, No. 1, pp. 83-92, ISSN 1748-5851.

Sol, D. & Senar, J. C. (1992). Comparison between two censuses of Feral Pigeon Columba livia var. from Barcelona: an evaluation of seven years of control by killing. *Butlleti del Grup Catala d'Anellament*, Vol. 9, pp. 29-32, ISSN 1130-2070.

Sol, D. & Senar, J. C. (1995). Urban pigeon populations: stability, home range, and the effect of removing individuals. *Canadian Journal of Zoology,* Vol. 73, No. 6, pp. 1154-1160, ISSN 0008-4301

Sossinka, R. (1982). Domestication in birds. *Avian biology* Vol. 6, , pp. 373–403, ISBN 0122494016

Sutherland, W. J. (1996). *Ecological Census Techniques: a Handbook*. Cambridge University Press, ISBN 052147244X, Cambridge.

Wagner, G. (1972). Topography and pigeon orientation. In: *Animal Orientation and Navigation,* S.R. Galler, K. Schmidt-Koenig, G.J. Jacobs & R.E. Belleville (Eds.), 259-273, NASA, ISBN , Washington DC.

Williams, D. E. & Corrigan, R. M. (1994). Pigeons (rock doves). In: *The Handbook: Prevention and Control of Wildlife Damage,* S.E. Hygnstrom, R.M. Timm & E.G. Larson (Eds.), E87-E96, University of Nebraska, Lincoln, Available at http://tinyurl.com/3nwtx6x

Williams, B. K.; Nichols, J. D. & Conroy, M. J. (2002). *Analysis and Management of Animal Populations: Modeling, Estimation, and Decision Making*. Academic Press, San Diego, ISBN 0127544062

Yoder, C., Avery, M. & Wolf, E. (2006). Nicarbazin: an avian reproductive inhibitor for pigeons and geese. In: DigitalCommons@University of Nebraska – Lincoln, Available from http://tinyurl.com/3r6vxk6

Yoder, C. A.; Miller, L. A. & Bynum, K. S. (2005). Comparison of nicarbazin absorption in chickens, mallards, and Canada geese. *Poultry Science, Vol.* 84, No. 9, pp. 1491-1494, ISSN 0032-5791

Zucconi, S., Galavotti, S. & Deserti, R. (2003). I colombi in ambiente urbano - Sintesi del progetto di ricerca Nomisma. *Disinfestazione,* Novembre/Dicembre 2003, pp. 9-21.

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How to reference

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Dimitri Giunchi, Yuri V. Albores-Barajas, N. Emilio Baldaccini, Lorenzo Vanni and Cecilia Soldatini (2012). Feral Pigeons: Problems, Dynamics and Control Methods, Integrated Pest Management and Pest Control - Current and Future Tactics, Dr. Sonia Soloneski (Ed.), ISBN: 978-953-51-0050-8, InTech, Available from: http://www.intechopen.com/books/integrated-pest-management-and-pest-control-current-and-future-tactics/feral-pigeons-problems-dynamics-and-control-methods

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